ERECTING AND INSTALLATION WORK

A PRACTICAL GUIDE IN THE ERECTION AND INSTALLATION OF MACHINES AND STRUCTURES ON SITE

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WITH ONE HUNDRED AND FORTY-TWO ILLUSTRATIONS AND DRAWINGS

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PREFACE

THE benefit of the high-precision work which goes to the making of present-day engineering appliances, such as engines, pumps, machine tools, electric motors, and their associated drives can only be derived by the user, providing the utmost care is taken to ensure that the plant is properly erected and installed on the site.

The information contained in this book has been collated to provide erectors and installation engineers with a sound reliable guide on the procedure to be adopted in dealing with the various types of engines and power-driven machinery.

Although, strictly speaking, the electric motor is not a prime mover, in that it does not generate its own power, it is quite legitimate to regard it as the prime mover in an electrically driven factory, because it provides the source of power for setting all the production machinery of such a factory in motion.

In the chapter dealing with electric motors will be found much useful information regarding the installation of belt rope and gear drives. The erection of line shafting and the installation of machine tools, including power hammers and similar heavy machinery, complete the treatment.

Whilst it is believed that all the main problems likely to be met with in erecting and installation work have been dealt with in this book, any suggestions for extending the treatment in later editions will be gratefully received, and will be given most careful consideration.

E. M.

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ERECTING AND INSTALLATION WORK

Chapter I

ERECTING PRACTICE

IN engineering assembly, it is the usual practice, and it is always the best practice, to erect any machine, engine, or even structure, in the maker's shops. It can then be dismantled, suitably marked, and sent to site.

There the erection will be carried out under somewhat different conditions. Generally, facilities will be less, and the man on the job will have local problems to solve, often by improvisation.

This chapter will help the man on the spot, for the cases quoted, or the examples given, can always be adapted to other ends.

Fitting Castings

Even to-day, a considerable amount of fitting of castings to woodwork and still more to plated work has to be carried on.

Examples of this may be quoted in connection with cranes and other lifting appliances, or any structure which does not employ a cast-iron framing as a basis. If necessary, the wood is sawn, adzed, or chiselled to suit the castings, holes for bolts are bored, and may be burnt through smooth and true. If two castings must retain an exact relationship, they can be tied together by bolts passing through lugs provided for the purpose. Thus any swelling or shrinkage of the timber cannot affect the relationship.

Fitting to plates, angles, T's, channels, girders, plain and built-up, entails some degree of skill and care, not only to align bearings and other elements correctly, but also to impart permanence to the fit, so that the castings will not work loose after a short time, and move about in their seatings and around bolts.

The Bolts to Use

For re-erection reasons two or more "turned" bolts will sometimes go along with the rest of black quality, to be sure that the casting will be replaced quite accurately, as the turned bolts fit tightly in reamed holes. But if the work is sent away assembled, black bolts throughout may suffice, or often rivets. Best-class construction has all turned bolts in reamed holes.

"Black" Fits

What are termed "black" fits, though not so common as formerly, persist in numerous instances. No machining occurs for these, and little

or no hand work, but castings, forgings, plates, bars, and so on are bolted or riveted together with surfaces as left from the manufacturing process. Black bolts also go in cored, punched, or rough-drilled holes, with little pretension to close fit. The only attention which may possibly have to be given to these more primitive sorts of union is prevention of rocking, that is a little chipping just to ease high spots and let the faces bed together without that fault.

Method of Procedure

Two main conditions require to be fulfilled when fitting a casting.

(1) Good contact with the structural steel, and (2) correct location, which is a constant necessity because so many details occur in pairs for the reception of shafts and other items.

Good bedding on the steel must be ensured by chipping and filing, or grinding the parts of the rough casting as necessary. Sometimes the strips (or the steel as well) have been planed or milled, making work easier for the fitter.

Testing for Bedding Fit

The preliminary test consists in laying the casting on and trying it for rocking. Should fitting between flanges or angles be needed, this does not apply, because the portions of the chipping strips at the edges must be reduced until entry is effected. To do this carefully, contact is ascertained by painting the steel, or brushing with red-lead paste; when the casting is tried in, the colour indicates the state of fitting. Eventually bedding down to the web or plate occurs (Fig. 1) and the contact of facings may likewise be tested with colouring. In this

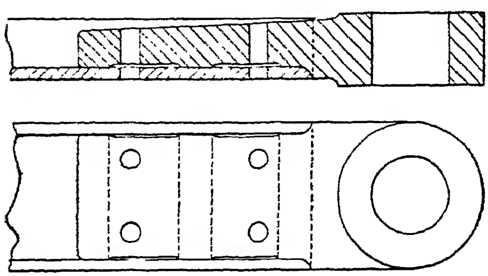


Fig. 1.—Simple example of fitting casting to channel section by facing-strip contact

The facing strips diminish the amount of chipping or filing that would be necessary to get proper fitting of casting to channel.

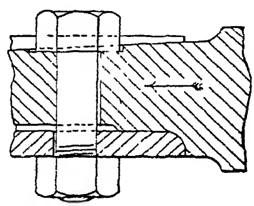


Fig. 2.—Fitting casting to channel section

Showing method of drilling holes slightly out of line so that bolt will pull up casting against end of channel.

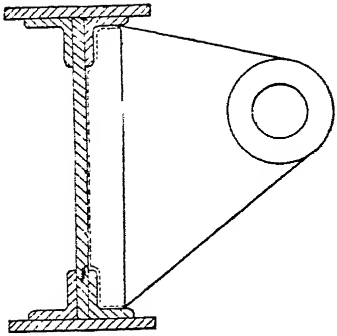


Fig. 3.—CASTING FITTED OVER ANGLES AS WELL AS PLATE

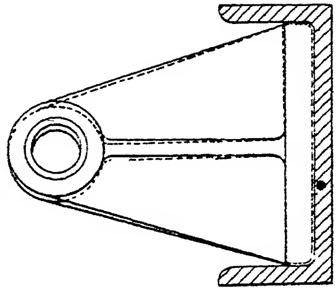


Fig. 4.—TWO BEARINGS NOT IN ALIGNMENT

The foot of one must be filed to throw it into alignment.

specimen, fitting against the end of the channel has to be seen to, filing the steel to match the radius in the angle of the casting.

Drilling Bolt Holes

If turned bolts have to be used, the holes in the web are put through, guiding the drill by those already in the casting, then reaming. During the operation a couple of screw clamps hold the parts in place. When black bolts go with a fitting of shouldered type, the holes for the web should be scribed through from the casting, and the drilling done very slightly away from the end.

This will pull the casting hard up against the channel end, as in Fig. 2. The job is complicated if a built-up girder is met with, because snug fitting must be obtained on both plate and angle (Fig. 3). This entails careful rubbing with the steel painted with colouring, and examination of the spots on the casting. Frequently a thickness plate is inserted across between angles, so permitting a level foot to be used on the bracket.

Alignment

Occasionally exact setting does not become necessary, so long as the bedding has been well executed, but very many bearings must lie true with one another. Where tilting is present, the facings must be chipped and filed until the requisite throw has been given. For instance, two bearings (Fig. 4) are aligned by dealing with the foot of one of them, so correcting the fault seen. Observation is variously effected by sighting through, by using a straight-edge in the bores, and most definitely on inserting the shaft, and attempting to bolt the brackets to the girder. If the shaft cannot be rotated, careful note must be taken of the way one bracket springs away when the bolts are loosened, and its strips reduced as necessary to bed down without binding the shaft.

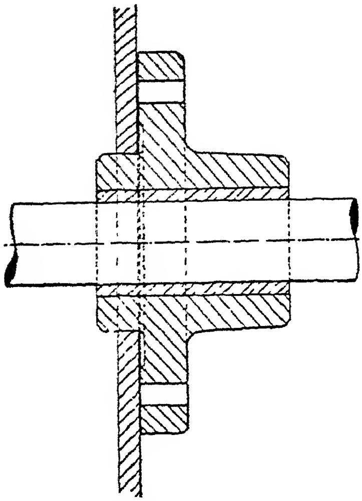


Fig. 5.—BEDDING SPIGOTED BEARING AGAINST PLATE

Metal needs removing around the lower area of the facing in order to bed properly against the plate.

Spigoted Bearings

A spigoted bearing, of the style Fig. 5, shows more easily where contact with the plate fails. Filing is performed according to evidence at first supplied by glancing around the flange, and later with a feeler gauge (Fig. 6), one or other of the leaves being tried under. In bad cases, it may be that the flange will have to go back to the lathe for facing off at a slight angle to match the plate.

Adjustability

Certain kinds of work, requiring adjustability of bearings and other details, must have slotted feet to allow movement over the hold-down bolts or screws.

Use of Clips

A valuable alternative is to fit clips, of which there are several designs. Some utilise bolts reaching up each side of the girder, to a clamp-plate across its top, but generally a grip is obtained on the flange, as in Fig. 7, for example.

Lateral adjustment for aligning purposes often takes place through the medium of a screw in each lip pressing

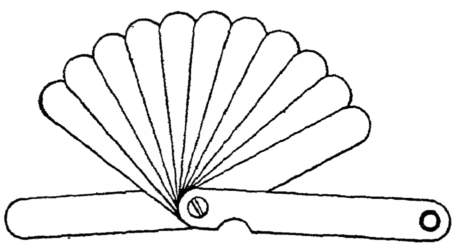


Fig. 6.—FEELER OR THICKNESS GAUGE

One of the several types. This has a set of blades of successively graduated thicknesses. It is used to ascertain defects in the fitting of parts, as well as amounts of clearance.

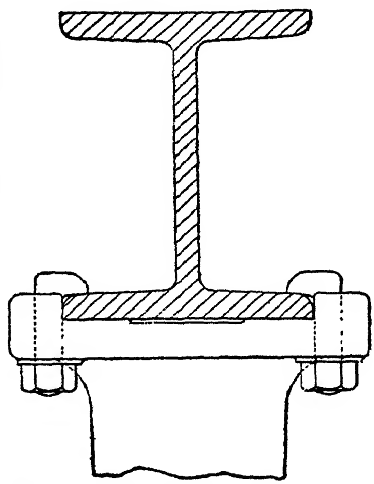


Fig. 7.—FASTENING A CASTING TO STRUCTURAL STEELWORK

One of the many ways to do this without drilling bolt holes in the girder. Changes of position may be readily effected.

against the edge of the flange. A considerable proportion of mill-wrighting practice shows clipping methods, for bearings disposed above, below, or at the side of structural members, also other parts, in connection with belt-striking apparatus, etc., no holes being drilled for any such attachments.

Fit of Bolt Head on Flange

It may be noted that under circumstances where bolts do pass through, the fit of the head at the sloping side of the flange must be made right either by turning or filing the underside of the head to an appropriate angle, or interposing a bevel washer of correct angle. Another scheme is to use a facing cutter in an arbor and cut a circular seating square with the hole.

CLOSE FITS: METHOD OF ASSEMBLY AND SEPARATION BY BLOWS OR PRESSURE

A considerable proportion of fitting practice is concerned with making various kinds of close fits, for shafts, spindles, pins, bolts, bushes, liners, collars, rings, washers, and other component parts. Different degrees of tightness are given according to the class of work and the duty involved.

Close Fits

Shafts and other details may be a push fit, which is too tight to revolve without seizing. It may be a driving fit, requiring hammer blows or some sort of mechanical pressing appliance for assembly. Or a force fit, demanding hydraulic pressure to assemble, or expansion of the hole by heat, followed by shrinkage. Sometimes slight or considerable taper is given to make a tight fit; in other instances the parts are parallel.

Additional Holding

Supplementary hold may be essential positively to lock the fit against endlong or circular displacement, but only, for example, where vibration is excessive, the parts cannot be reached owing to their constant movement, or misplacement would have very undesirable or dangerous consequences.

Methods of Fitting

Methods vary according to the shape and size of the components, the relative tightness of fit, and whether a few or a large number of pieces have to be dealt with. The simplest way is by direct blows. Other systems include bolt or vice pressure, screw lever or other mechanisms. A good deal of the forcing which was formerly accomplished by hammer or vice action is now effected in vertical presses originally intended for forcing work on and off turning arbors.

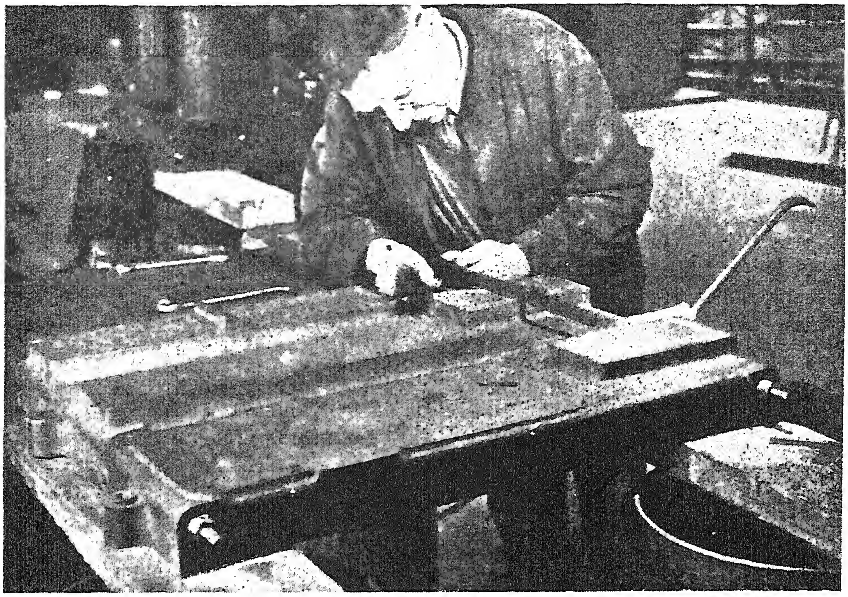


Fig. 8A.—Erecting a "Tecalemit" pilot pressure oil dispenser

This shows the laying and lining up of the bedplates. One to eight pumps can be added to the same unit, if required. (*By courtesy of Tecalemit, Ltd.*)

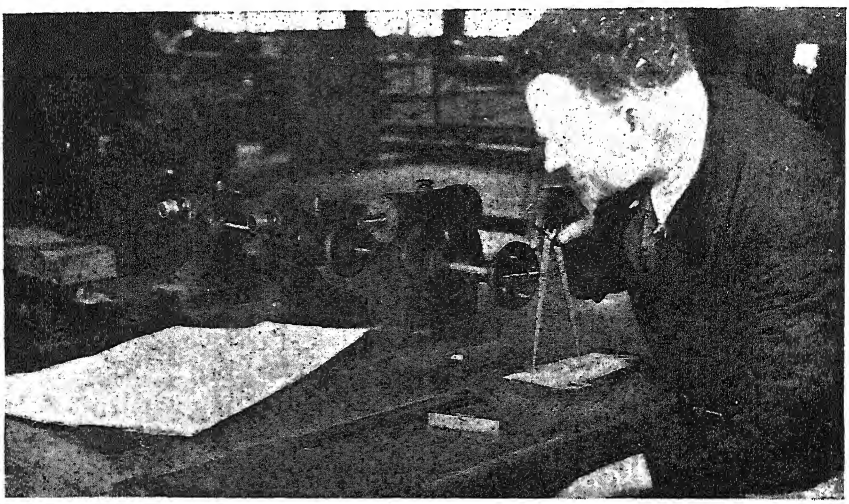


Fig. 8B.—Erecting a "Tecalemit" pilot pressure oil dispenser

Marking off bedplate for position of pumps.

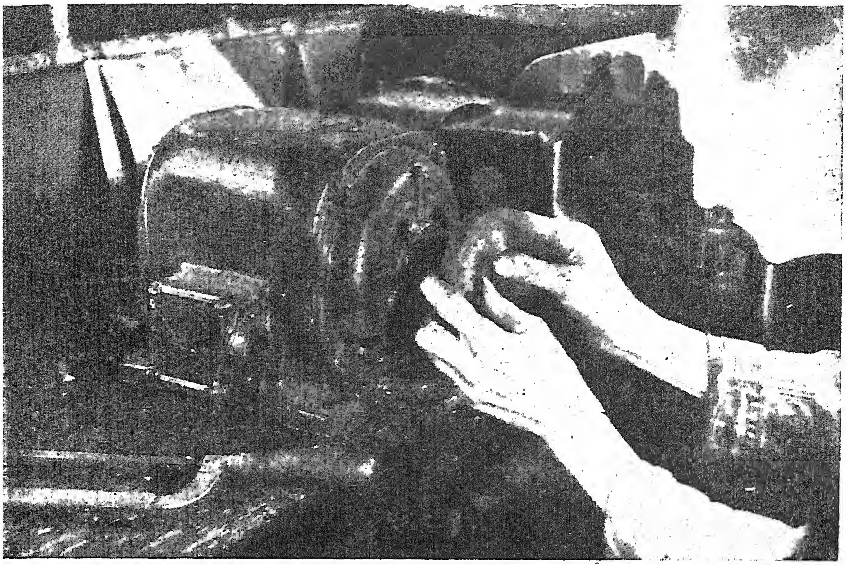


Fig. 8c.—Erecting a "Tecalemit" pilot pressure oil dispenser
Fitting the motor coupling.

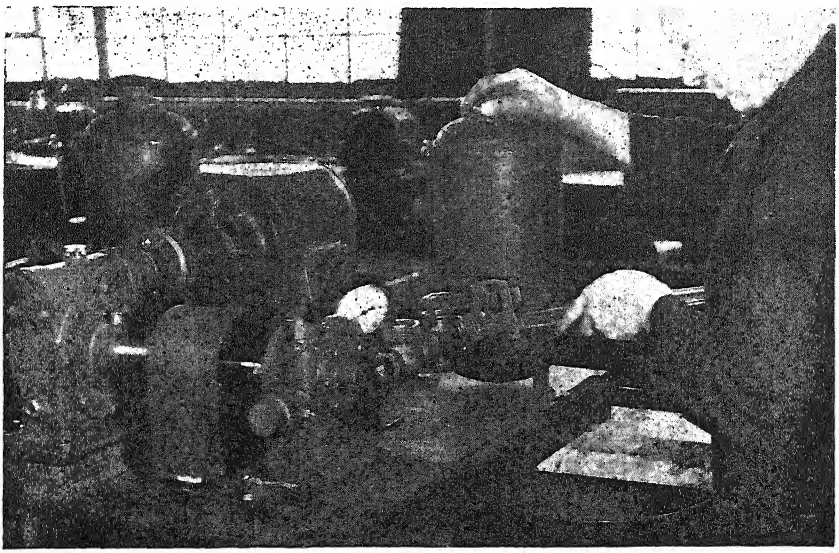


Fig. 8d.—Erecting a "Tecalemit" pilot pressure oil dispenser
Connecting up a pilot pressure chamber.

Preliminary Treatment

Before commencing to put together any of the pieces mentioned—shafts, pins, bushes, liners, etc.—the character of the machining has to be taken into consideration. Working to the fine limits usual in good practice, there may be little or nothing for the fitter to do, but in some jobs accuracy is not so satisfactory, so that file and scraper come into employment.

Removing Metal

Tentative fitting is perhaps necessary, trying the parts together and removing metal accordingly if the fit is too tight—that is, likely to burst the hub or other surrounding element. The hole might be enlarged with smooth half-round file, or scraped if very little has to come out. The shaft may be filed circularly or draw-filed.

Clean Surfaces

Care must be taken to have the surfaces perfectly clean from bits of metal, and oiled before union, or seizing will occur. Short bushings and rings need careful starting to avoid risk of getting across the hole and becoming strained and damaged. A short taper at the beginning will often assist, but if a press of some kind is utilised the ram will set the ring straight.

Assembly by Hammering

Much is done at a bench or on the floor with rawhide or wood mallets. The latter are of heavy, long-handled type for shafts of good diameter, and are used considerably for fitting feather keys, when a relatively short shaft has to be driven in and out of a wheel in the course of the operation. No damage is done to the shaft, but nearing the completion of fitting, a sledge hammer and a lead, copper, or brass block come into use for getting the final force necessary. A recess is drilled in the centre of the block to provide space for the upstanding bit of metal often left from centring for the lathe or grinder; this is cut away after everything has been fitted and correct. Small work may be conveniently driven with a lead, copper, or brass hammer, or a steel one with block of hardwood, or some softer metal or alloy than the part under treatment interposed.

Bolt Pulling

Steady, equable, and powerful force can be applied by a simple rig-up of bolts and plates, either to draw parts together or separate them without damage. The smaller examples are notably brasses or bushes, which would be liable to suffer injury and distortion by any sort of

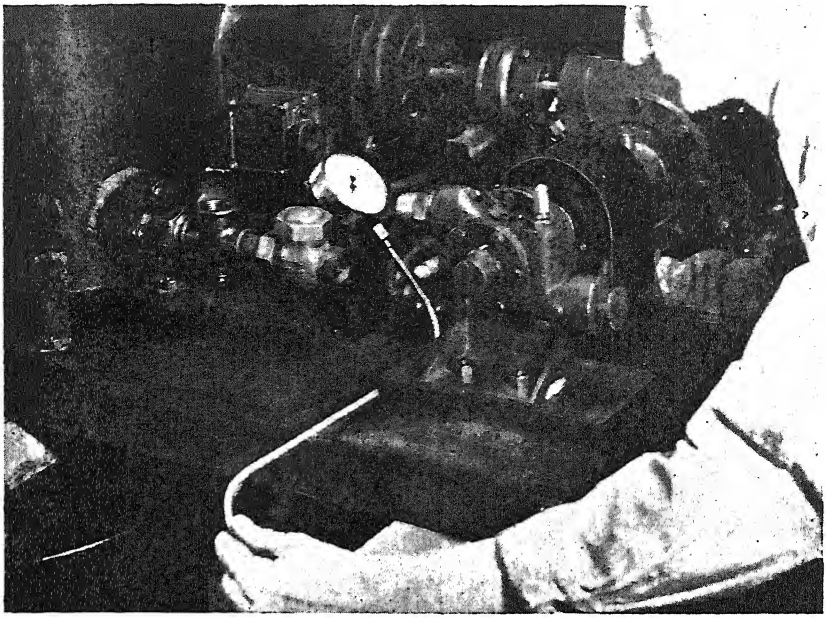


Fig. 8E.—ERECTING A "TECALEMIT" PILOT PRESSURE OIL DISPENSER
A further stage. Fitting the pressure pipes.

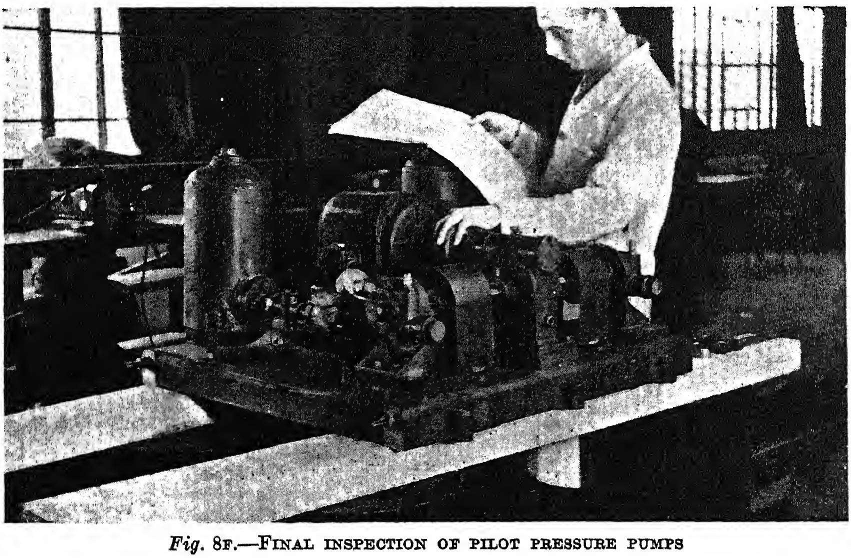


Fig. 8F.—FINAL INSPECTION OF PILOT PRESSURE PUMPS

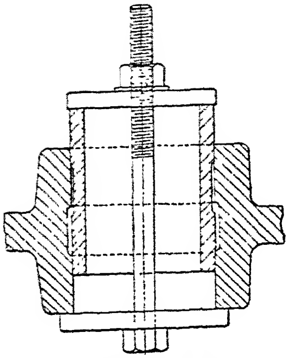


Fig. 9.—METHOD OF PULLING IN BUSH WITH NUT AND BOLT

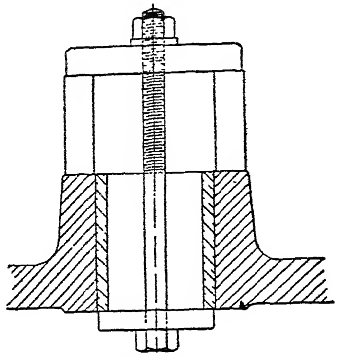


Fig. 10.—METHOD OF REMOVING BUSH WITH NUT AND BOLT

hammering. Bolt arrangements for insertion and withdrawal are shown in Figs. 9 and 10, the bush being started in gently with a block of wood and hammer, then the plates and bolt arranged.

Pulling Wheels on Shafts

If there is no shoulder on a shaft to take a pull against, bolts can be held after the manner of Fig. 11. A clip is bolted on to the shaft; against this rest the bolt washers, so that the wheel can be forced along by turning the two nuts equably. When two such wheels come at opposite ends of a shaft long bolts may pass through their arms and both be drawn on until the shoulder seatings have been reached.

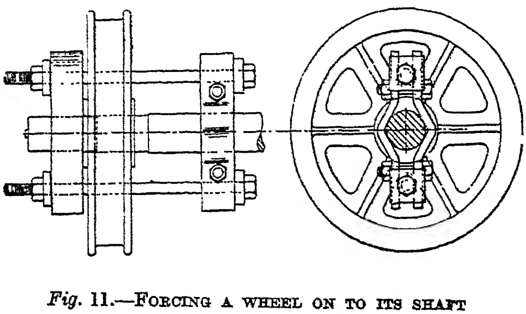


Fig. 11.—FORCING A WHEEL ON TO ITS SHAFT

By turning the nuts the wheel is pulled along the shaft.

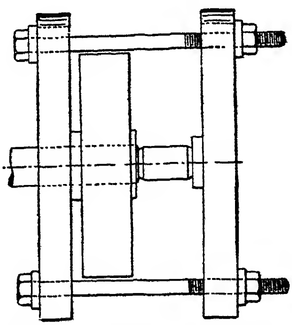


Fig. 12.—PUSHING SHAFT OUT OF WHEEL

Using plug and bolt pressure. The plug is smaller than the shaft.

Removal of Wheels

Fig. 12 deals with a pulling-off operation, with the assistance of a plug smaller than the shaft, so as to thrust against the latter until the wheel comes free.

Special Wheel-pullers

Several designs of wheel-pullers are available, possessing quick adjustment to suit different diameters of wheels, pulleys, gears, and flywheels. A central screw presses in the centre at the shaft end, and a cross-beam carries two or three hooks or chains to reach around the back edges of the wheel.

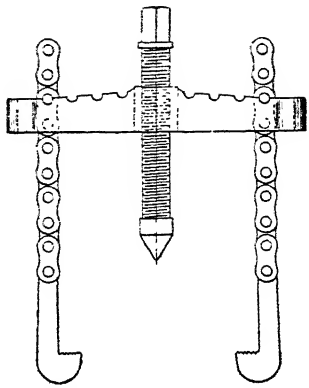


Fig. 13.—WHEEL-PULLER
The hooks catch on back of wheel and the screw presses on shaft end.

Forcing in the Vice

A well-made vice offers a useful medium for pressing in pins, bushes, and other details with less fuss and injury than the hammering method may involve. Protection is usually required in the form of soft clams to prevent the jaws from causing indentation, and a slab of wood or metal may be advisable to spread pressure uniformly all over the face of a bush. Abstraction calls for a plug, Fig. 14, passing into the hole, with either two packings or a ring at the back.

Fitting Bearings

Good fitting and maintenance of shaft and spindle bearings is of vital importance in most classes of mechanism. Many conditions have to be fulfilled—excellent contact, effective lubrication, avoidance of overheating, and prevention of settlement. For some services, notably in machine tools, accuracy of running demands very special treatment, because very slight inaccuracies will be reproduced in some way on the product.

Taking up Wear

In a few examples of slow-running or unimportant shafts no means for take-up of wear is given, but generally there must either be a mechanical adjustment, or renewal of the bearing surface by rebushing, or running-up with white metal.

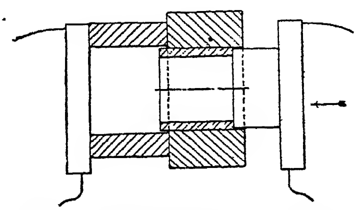


Fig. 14.—EXTRACTING A BUSH IN A VICE
Using a plug and packing ring.

Types of Bearings

There are a great number of differing forms of bearings, large and small, slow-speed and high-speed, and it is impossible to indicate all the varieties extant. But as affecting the fitter, the main points are whether a solid (or dead-eye) shape is chosen, or whether there are divided "brasses." Also if adjustment is obtained by means of a cap held down by bolts or screws, or if there is more elaborate contractile effect with a bushing opened or closed by some kind of screw or wedge device.

Some of the older shapes of brasses have largely disappeared from ordinary application, being displaced by more easily machined ones. This refers particularly to those of contour resting in square or octagon seatings. Though such are still retained in certain cases, a vast number are turned to fit bored seatings, which greatly simplifies both machining and fitting processes, and gives good results. Moreover, by slightly raising the shaft, a lower brass can be twisted out around it for inspection of condition.

Essentials in Ordinary Fitting

A properly fitted brass must bed well in the housing, and the shaft must make contact all over the bore. If bedding has not been done efficiently two or three undesirable things may happen. Change of alignment will occur when the brass becomes compressed on the high spots, or when it springs by weight or undue pressure. Vibration may also be set up. Furthermore, imperfect contact will often be detrimental because heat is not conducted away from the brass into the housing as fast as it should be.

Commencement of Fitting

It is not quite so easy to ascertain the state of contact of a brass fitting in a square or octagon manner, as it is with a circular one. Hence the greatest care should be taken over the machining, to finish the flats true, and not spring the brass in clamping, so that it may possibly distort on removal from the planer, shaper, slotter, or miller.

Square and Octagon Brasses

The bed surfaces should be lightly filed for smoothness, then the flanks of the brass will push down (Fig. 16). A thin coat of redlead marking smeared on the bed will reveal the state of contact when the brass is gently hit down with a rawhide hammer, or a steel hammer and hardwood block. Moreover some indication of the fairness of bedding will be afforded by the sound and the deadness or otherwise of the response to the blow. Some bearings requiring height adjustment do not rest direct on the bed, but upon a wedge which is moved across by screw pressure to regulate the elevation. In this case the wedge fits against a

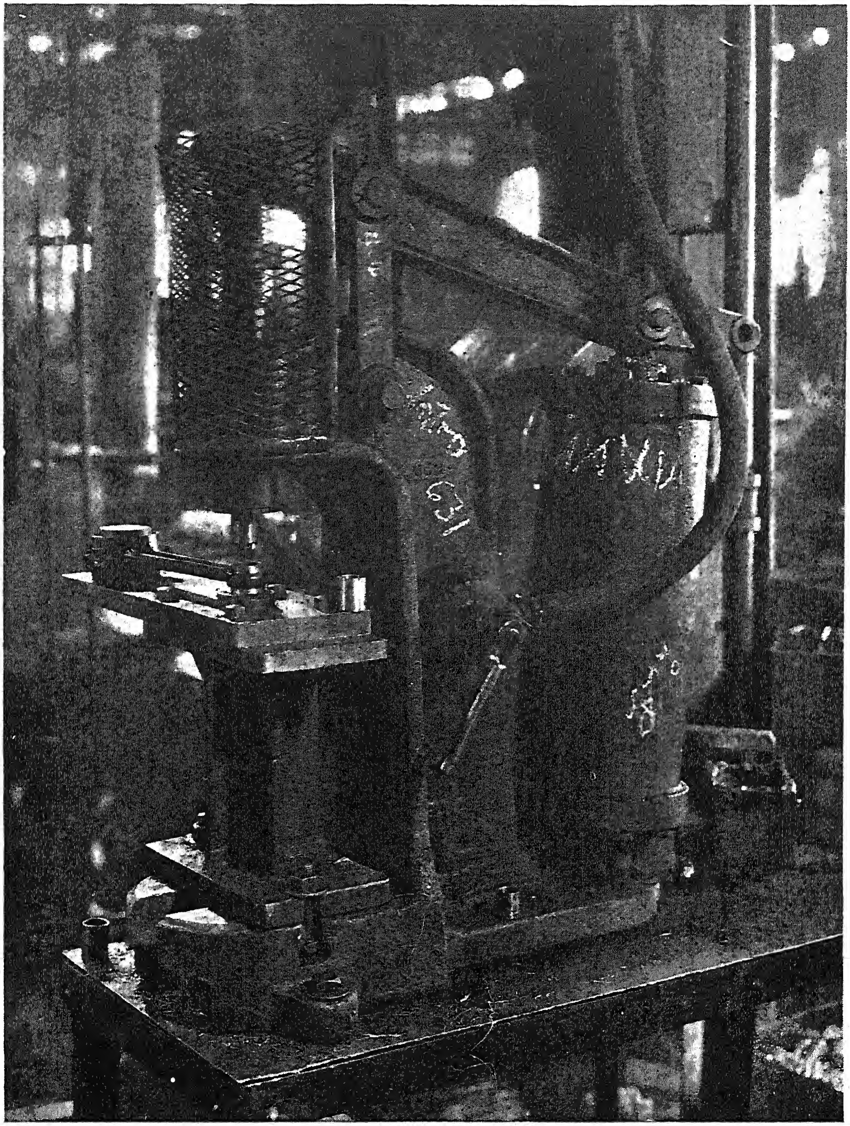


Fig. 15.—Arbor press used for pressing bush into connecting rod

The location of the connecting rod to bring the small end under the ram is by means of a stud on the table. The deep open-slotted stand under the table often serves to take shafts or tubes vertically.

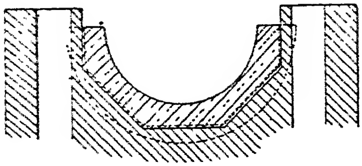


Fig. 16.—AN OLD TYPE OF BEARING BRASS

Showing a flanged brass fitting in an octagonal seating.

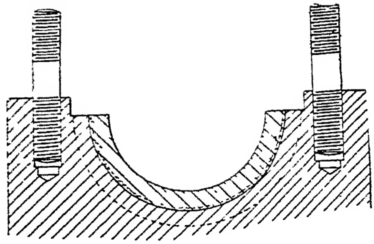


Fig. 17.—POPULAR TYPE OF BEARING BRASS

correspondingly sloped face under the brass, and close contact must be ensured for the sake of rigidity.

Semicircular Brasses

Faults which may require correction concern want of true circularity in the seatings, because of spring in the boring-bar; and similar inaccuracy in the brasses on leaving the lathe. Brasses run up with white metal may be likewise untrue from distortion induced by the heat. The first proceeding is that of filing off the sharp edges where the seating meets the end faces, so that the brass (which often has a radius in the angle) will not make a false impression of fitting. The faces next require touching off with a smooth file until the flanges of the brass will slip over them snugly (Fig. 17). Any faults found in lack of proper contact of the respective curves are generally more easily corrected by filing the brass.

Use of Redlead

To find where the contact spots are, the bed is thinly smeared with redlead paste, the brass put in place, and twisted to and fro in a short arc. The areas where marking becomes transferred need judicious filing, blending the curve neatly so as not to spoil the fit by leaving a series of irregular curves. Considerable discretion and restraint are essential in order to secure good results in the minimum time. Nearing the termination of trials the marking should be very thin indeed, so as not to mislead the eye, which will look for bright spots around the brass. In some bearings the cap does not fit the top brass by this semicircular contact, but is of the squared-out style.

Trying in the Shaft

There may be only two bearings, or several in line to support the shaft. In a solid bed adjustment for vertical position of the brasses does not usually come into the question, but for bearings set on girders or line-

shafts either packing or screw adjustment must be employed. The ball-and-socket or swivel bearing is also much liked as it aligns itself automatically. After taking off the sharp corners of the brasses the shaft is laid in the lower halves. But generally the safer plan is to try each half-brass on the shaft, in case it is tight across the edge (Fig. 18). Should this be so, trouble will arise when the shaft is put in, by its jamming. If tightness is present, the difficulty may be remedied with a fine half-round file, or a scraper, according to the amount requiring removal, until proper bedding occurs.

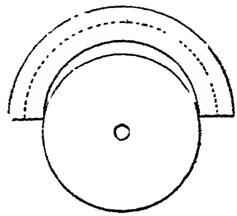


Fig. 18.—TRYING BRASS ON SHAFT BEFORE COMMENCING TO FIT

If tight across the edges, scraping must be done until the brass beds well down.

Testing the Fit

Marking is rubbed on the shaft, so that by its transference to the brass the places of contact with the latter will be shown, if the shaft is turned round. A light shaft can be twisted by the hands alone, a somewhat heavy one with a lathe carrier pinched on. When this is inadequate, there may be a wheel or pulley on the shaft serving as a lever. Failing such aid, a clamp bar can be rigged up after the style on Fig. 19, protecting the shaft with a strip of brass, copper, or leather before tightening the bolts.

Bearing Scrapers

Filing need only be resorted to in very bad cases, the scraper being usually sufficient. By its use a considerable quantity of metal can be taken off, or an extremely fine amount, with high degree of smoothness. For this effect the edges must be ground finely, and oilstoned to remove all traces of roughness.

Completion of Fitting Bearing

When the shaft has been well bedded down in the lower brasses, the caps are laid on, pulled down gently by the nuts, and rotation tried. Some variation exists in the precise way of procedure, since the cap may have to touch the housing directly, or a shim be laid between the faces. This can be removed later when wearing has made the bearing too large, and a thinner one substituted for take-up purposes. Assuming that direct contact is made, however, the shaft will probably be too tight to turn when the nuts are tightened, so scraping must be done in the cap when the high spots have

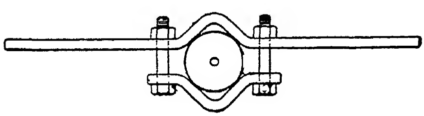


Fig. 19.—FOR ROTATING HEAVY SHAFT IN BEARING

Showing clip bolted on shaft to enable shaft to be rotated while trying for fit in the bearings.

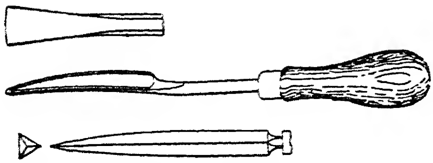


Fig. 20.—SCRAPERS FOR REMOVING METAL FROM BEARING AND OBTAINING ACCURATE FIT OF SHAFT

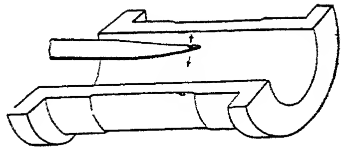


Fig. 21.—MOVEMENT OF HALF-ROUND OR TRIANGULAR SCRAPER

The scraper can be controlled to take off very small amounts of metal at any spot.

been detected by means of the redlead test, and continued, with intervals of trials, until the shaft will revolve by hand grip alone, making the best possible fit in the brass. Very thin marking towards the final stages will obviate the danger of thinking that the shaft is touching well, which it will appear to do if the layer is thickly applied.

Bushed Bearings

In addition to several variations in arrangements of divided brasses to suit pressures acting in certain directions, with adjusting features not possible on ordinary styles, solid or split bushes are adopted very extensively.

Solid Bushes

Solid bushes are fitted to the shaft or spindle by scraping, and trials with redlead, as already described, but their limitations arise in the finer classes of mechanisms where slackness which develops cannot be permitted. Remetalling must be performed, or, as in numerous instances, the bushing embodies a take-up action enabling close adjustment to be made according to the requirements, and the lubrication conditions. Among the finest work is that of machine tools, the higher precision types demanding extremely close contact, with only sufficient clearance for a very thin film of the best oil. Speeds are often high, so that the scraping has to be well effected, for proper bearing contact all over the journal.

Adjustment of Split Bushings

A split bush may be contracted by the direct pressure of the bearing cap, or by screws fitted thereto. Many bushes are tapered on the exterior to fit the eye of the bearing, so that when moved into the latter by nuts, contraction will occur. Occasionally the bush is solid, but being cut with a series of longitudinal grooves inside and outside is sufficiently flexible to contract by the taper system just noted. Sometimes the split of a bush is left empty, but frequently is filled with a wood or fibre insert to prevent vibration and keep dirt out. A metal insert or shim of known

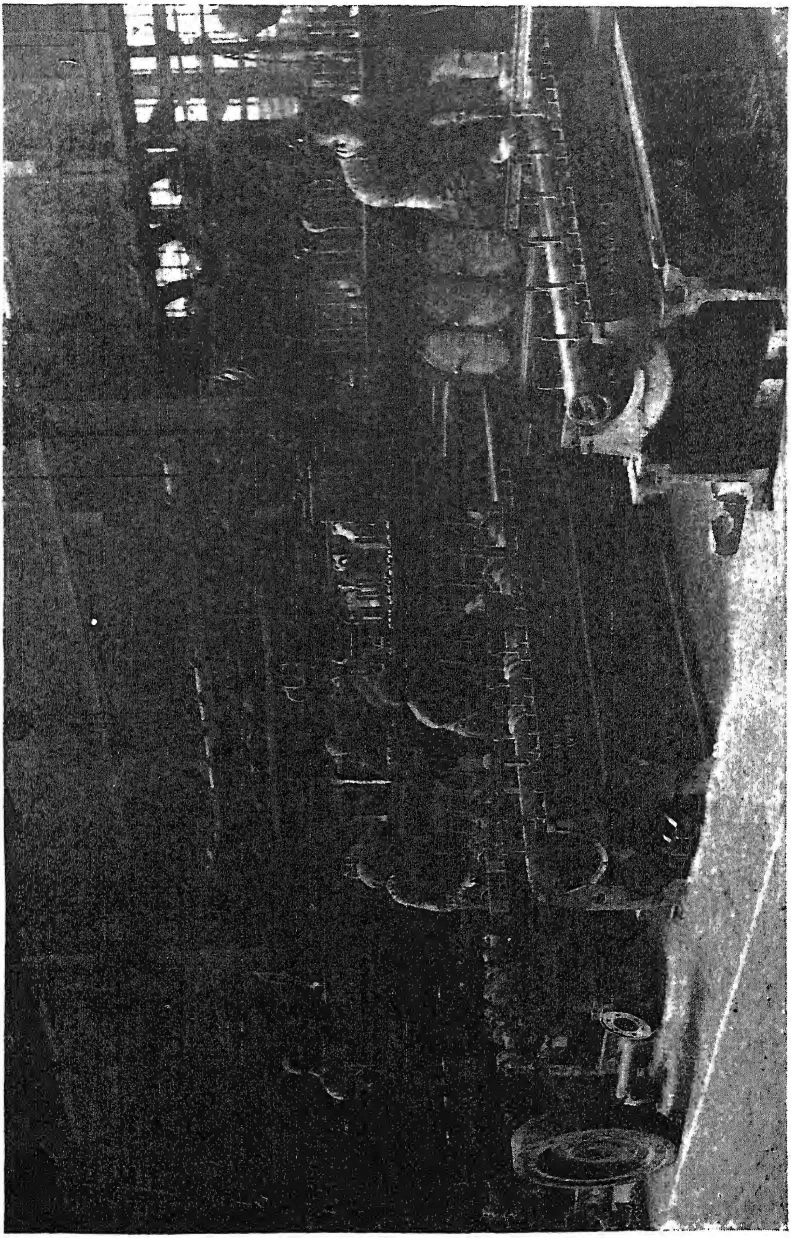


Fig. 22.—TESTING OIL-ENGINE BEARINGS FOR ACCURACY AND ALIGNMENT BY MEANS OF MASTER MANDRELS BEFORE CRANKSHAFTS ARE FITTED (*Ruston & Hornsby, Ltd., Lincoln.*)

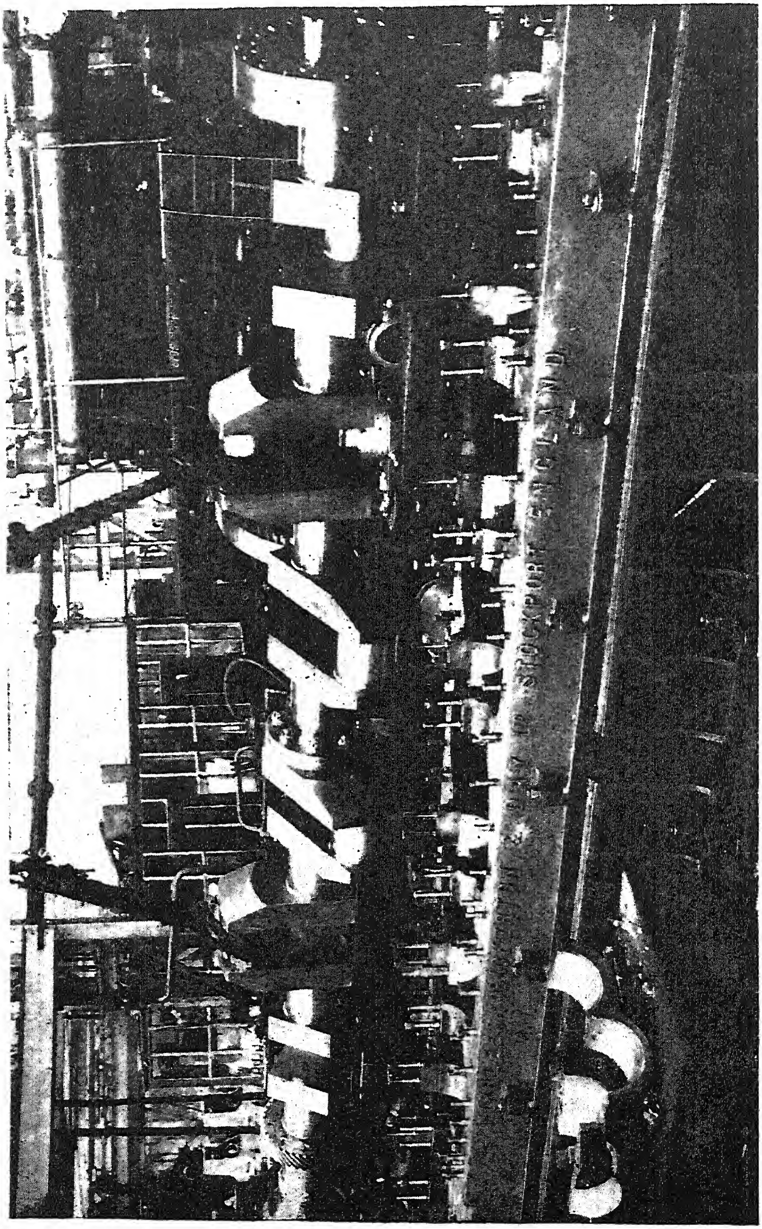


Fig. 23.—LOWERING A LARGE CRANKSHAFT INTO ITS BEARINGS

The engine is a 720 b.h.p. Diesel, being erected in the works of Mirrlees, Bickerton & Day, Ltd., Stockport.

thickness gives accurate control over the amount of closing; some shims are laminated, one or more leaves being peeled off when closing is necessary. Another way is to fit a taper-nose screw, or a screw-actuated wedge between the split for control.

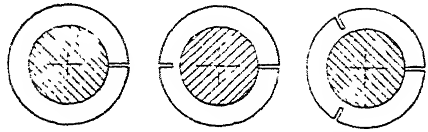


Fig. 24.—SPLIT BEARING BUSHES

Showing different means for take-up by closing in.

Bolt and Stud Fitting

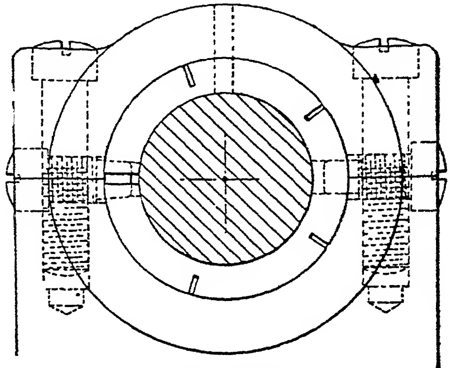


Fig. 25.—SPLIT BUSH CONTRACTED BY TIGHTENING THE BEARING-CAP

Two taper-end screws on the left act as controls for closing in the bush.

Work in connection with the fitting of screws, studs, and bolts has been greatly reduced by machine-shop processes, but much hand treatment persists. Operations necessary comprise drilling, reaming, countersinking, counterboring, tapping, screwing, and stud setting, with frequent use of file, scraper, and emery-cloth. Drilling is done chiefly when positions cannot be determined at the time of machining, or it is easier to effect the process when erecting.

Drilling

The familiar ratchet brace supplies a cheap and simple means of drilling in any sort of situation, but its slowness precludes use if an electric or pneumatic tool is available. The last-named are held in the hands for light work, but sustained by a drilling pillar when this procedure is not possible. For bolting or clamping to ordinary flat faces, the foot with slot, as shown, is essential, while a magnetic foot may also be had, carrying two

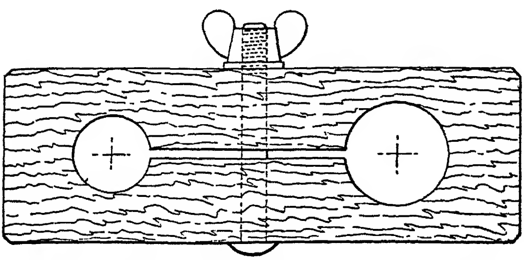


Fig. 26.—CLAM FOR HOLDING BUSHINGS WITHOUT INJURY

This grips two sizes by the tightening of the nut, and is held in the vice while the bores are being scraped to fit, or score marks removed.

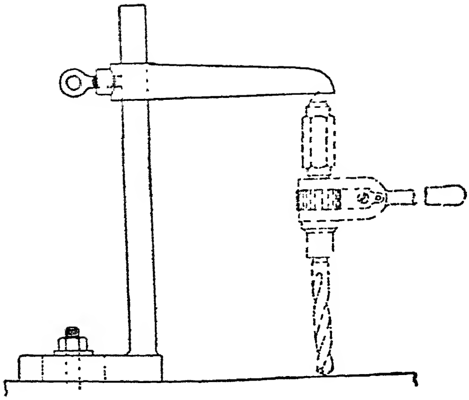


Fig. 27.—Ordinary drilling pillar

Used with ratchet brace or electric or pneumatic drill.

solenoids and screw for tilting the pillar so as to obtain even contact of the magnets on the work-piece.

Attachment to girders can be effected with a foot or palm as drawn in Fig. 28, hooked to catch under the flange, and secured by the adjustable clamp, which slides to the appropriate vee rest. As an alternative, the pillar may be inserted in the end, according to the dotted outline, for drilling the web.

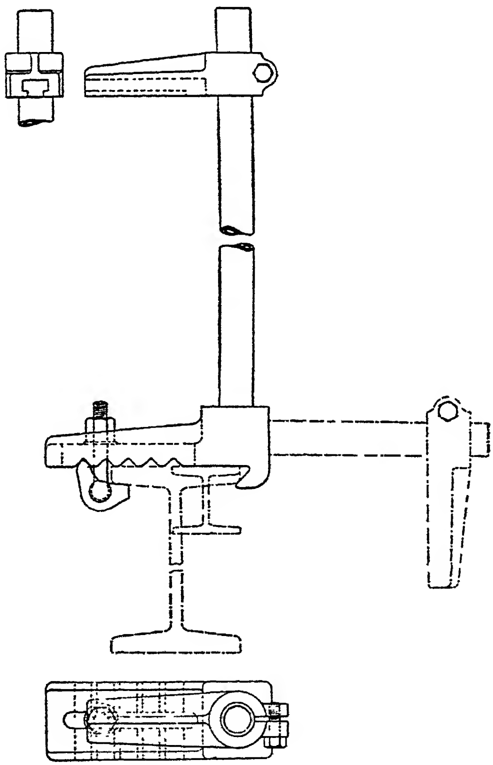


Fig. 28.—Drilling pillar having foot adapted to clip on to girder

Other Drilling Methods

Many positions may have to be found during course of erection, besides which on large structures mounted on the floor or a plate it is convenient to employ a portable drilling machine movable on trolley wheels, or slid about the floor-plate and bolted as required. A considerable proportion of holes are what might be termed transfers, that is, a drilled casting or forging from the machine shop being placed in position; location of holes for its connection are thereby found to put into an under girder, plate, casting, or forging. Marking through may be done with

a scriber, or if the member is deep, more accurately by either of the dodges in Fig. 29. The first carries a scratch needle to mark a true circle, the other is a piece of tube brushed with whitening solution on the end, so that when twirled it leaves a circle impression.

Another hint is to prepare a centre-punch of diameter to fit the hole accurately and with point ground central, thus enabling a pop to be struck for starting the drill, as well as for marking a reference circle.

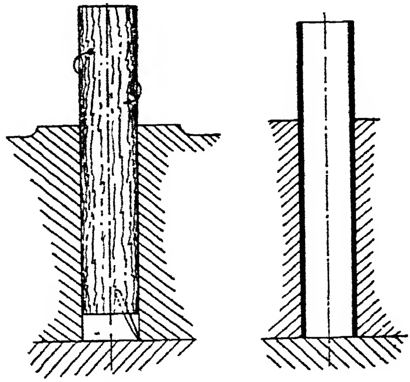


Fig. 29.—METHODS OF SCRIBING THROUGH DEEP HOLES ON TO SURFACES FOR DRILLING

The end of the tube in the second example is smeared with colouring matter.

Commencement of Drilling Operation

Having a circle thus struck, compasses are used to find its centre, and the centre-punch applied to give an impression for the drill point to start in. If a lubricant has to be fed on the drill, it is safer to centre-pop around the circle for permanent reference. After the drill point has penetrated a short way, it must be withdrawn, and the result inspected. If straying to one side is evident, "drawing" has to be done with a centre-punch, or a round-nose chisel, driving a recess (Fig. 30), which will cause the drill to move over on the next application. Drawing may have to be performed again, if the first effort does not suffice.

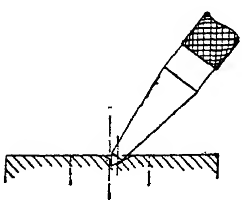


Fig. 30.—CORRECTING A DRILL POINT WHICH HAS BEEN STARTED OUT OF CENTRE

The point may be "drawn" over by driving a punch impression, as shown.

Drilling Through

Very often no marking becomes necessary, as the drill can be put through the part sent from the machining department with greater accuracy. Fixing during the process depends on the mode of union, but sometimes a couple of cramps are sufficient for retention of position. If a lot of holes have to be drilled, it is safer, after doing two near each end of the piece, to insert temporary or "tack" bolts in these.

Drilling at Close Quarters

The only unusual conditions experienced in ordinary work are those of extra deep holes and

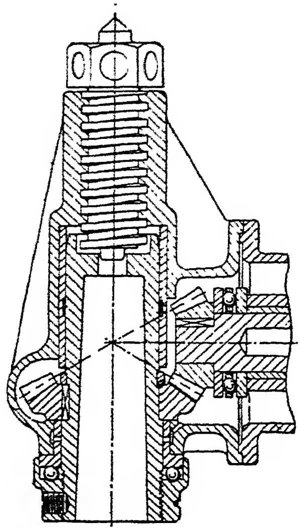


Fig. 31.—The extension end of a pneumatic drill

This drives the tool by means of a shaft from the engine, permitting operation close to upright faces.

those situated close to flanges and corners. For the one kind a special long drill becomes essential and for the other the ratchet brace, or a corner or close-quarter head of an electric or pneumatic drill, Fig. 31, which is sometimes also of low type for scant headroom and holds a stumpy drill.

Reaming

This is unnecessary excepting when bolts, screws, rivets, pins, studs, pivots, etc., must fit closely or it is required to line up and straighten two or more rough-drilled holes in mating parts. Much of the latter class of treatment is found in erecting, locations being ascertained, and the slightly overlapping rough holes then trued out to size. Structural work is severe on reamers, and strong patterns are utilised, having few teeth, and sharp taper for a distance, Fig. 32, while high-speed tools with quick spiral (corkscrew reamers) can be run at fast rates by pneumatic drills.

Hand Reamers

A spiral-fluted reamer is preferable to a straight-fluted one for many purposes, giving a smoother hole because of the shearing action, and if keyways or slots are present the finish is not affected by the teeth hitching therein, as might be the case with parallel flutes. When close accuracy has to be maintained, a roughing reamer can be applied first, and sizing effected by a finishing one, kept only for that service.

Expansion Reamers

Expansion reamers are much favoured, size being regulated very finely, notwithstanding repeated sharpening. Many designs have flat blades, fed out-

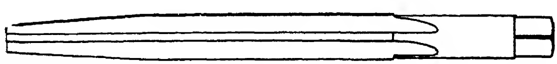


Fig. 32.—Strong "bridge" reamer for hard duties in structural work

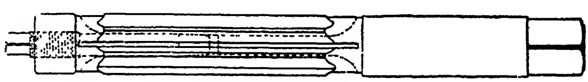


Fig. 33.—Adjustable reamer for accurate sizing

This has a limited amount of expansion by screwing in the taper plug.

wards by wedges or cones and locked, but the spring type, Fig. 33, is satisfactory for a large amount of hand reaming. It has splits along the body, permitting of a limited degree of expansion as the taper end screw is turned. The pilot at the end forms an accurate guide.

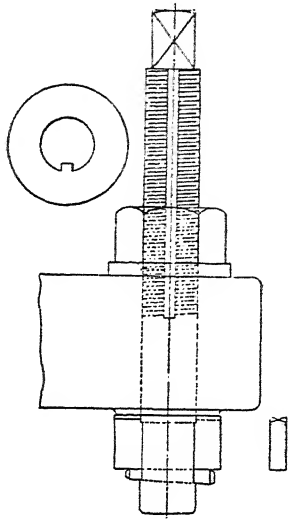


Fig. 34.—Arboring or facing tool

This squares up faces for reception of bolt heads, nuts, and flanged fittings.

Fit of Bolts

The roughest, cheapest sort of fit is by black bolts—not machined on the body—going in cored, punched, or rough-drilled holes. Location is not certain with these, but may be determined by a shoulder or spigot contact of the mating parts, or by dowels, plain close-fitting pegs. Turned or ground bolts in reamed holes furnish the best mode of union and separation and reassembly may be done at any time with certainty of accurate relations. Sometimes these bolts are just a push fit, in other cases are driven or forced in tightly, occasionally fitting by taper body for severe duties.

Facing Tool

If surfaces around bolt holes have not been machined and it is desired to have a true square facing for the turned head of a bolt or its nut, the fitter employs a facing or arboring tool, Fig. 34, rotated by a tap-

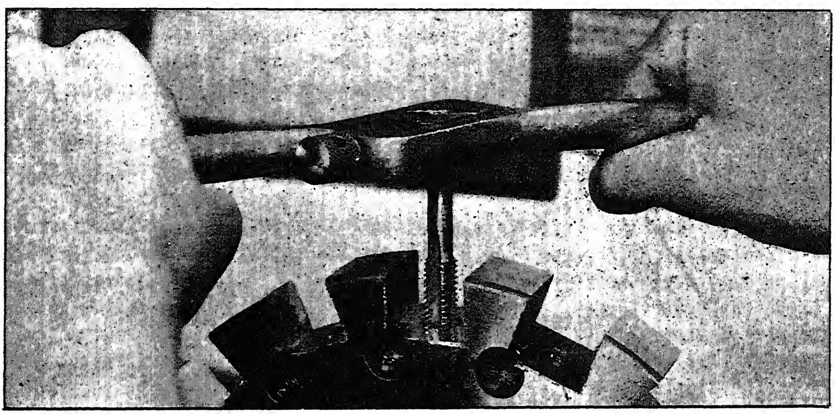


Fig. 35.—Cutting a female thread with a tap

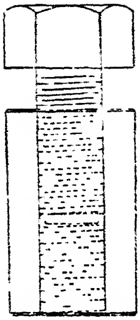


Fig. 36.—Stud block for screwing studs into place

The block is screwed on to the stud by hand until the setscrew touches the top, after which a spanner applied to the body of the block will cause the stud to screw in.

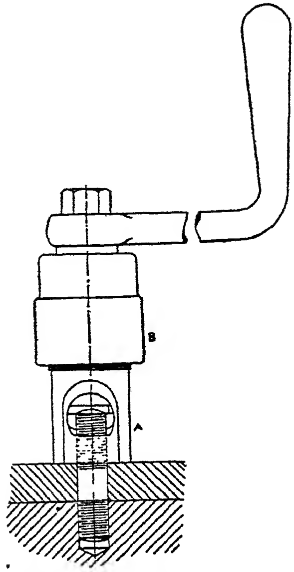


Fig. 37.—Tool for rounding off the ends of studs when in place and reducing them to uniform length

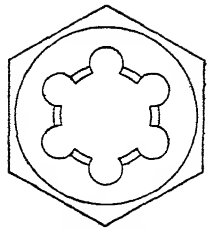


Fig. 38.—Die nut by means of which damaged threads on studs in situ may be cleaned up and sized

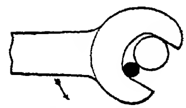


Fig. 39.—Stud removal

Using the biting-in action of the piece of file shown black.

wrench. The cutter is filed to shape, hardened and tempered, and the edges ground and honed to impart a smooth finish. Shouldered down to fit centrally in the arbor the cutter is locked with the wedge. Feed is given by slight tightening of the nut at intervals, and it does not slack back because the washer has a key (as seen in the detail) entering the groove of the arbor. Instead of the flat cutter, a stronger shape may be fitted, circular, with several teeth resembling those of a milling cutter.

Corrections

If a stud does not stand upright, or has been accidentally bent, a nut should be placed on it, and struck with the hammer; thus no injury will be done to the threads. Shortening after putting in place can be accomplished with file, finishing neatly with emery cloth; but if there is much of this, to reduce a set of studs to uniform height, the appliance outlined in Fig. 37 comes in handy. Socket A has to be screwed on to the stud, if necessary interposing a packing-piece to regulate the height to which trimming will be effected. On turning the handle the cutter will com-

mence to round the stud end, and screw feed is supplied by slowly twisting the sleeve B.

Use of Die-nut for Rescewing Damaged Studs

Because stock and dies cannot be manipulated after a set of studs has been fitted, a die-nut, Fig. 38, deals with bruised threads, cleaning them up neatly.

Removal of Studs

Two nuts locked together tightly on a stud will enable it to be abstracted, placing the wrench on the under one. Or, if damaging the stud does not matter, an old spanner and a piece of file (shown black), Fig. 39, causes positive rotation by the file biting into the metal. A tool sold for this function has an eye to drop over the stud, and the eye is pivoted to a long handle with a cam-shaped serrated end. On pulling at the handle the serrations dig into the stud and turn it.

PUNCHING

Many sheet-metal components, such as strips, covers, guards, lagging, brake straps, and much beside, require punching after positions of holes have been ascertained. Sometimes the operation takes place at the bench or vice, but often on the partly fitted mechanism, and the method depends on size of hole and thickness of material.

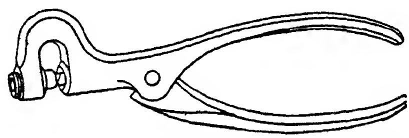


Fig. 40.—Hand punch for thin or soft materials

Thin and Thick Stuff

Thin soft stuff can be worked with a plier style of tool, Fig. 40, but for thicker substances and for locations where pliers cannot gain access, an outfit such as in Fig. 41 is required. The thin under leaf may be slid below a sheet slightly raised from its bed (for example a lagging sheet on a cylinder) and the punch driven through.

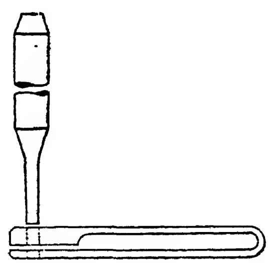


Fig. 41.—Hand punching outfit

For use on sheets on the bench or for work under construction. This punch may be employed on thicker stuff than can be dealt with by the tool shown in Fig. 40.

Fitting Cotters

This is a good test of the fitter's skill, as cottered joints are generally subjected to severe pushing and pulling, with sudden jolts and variations in pressure, particularly in engines and pumps. Poor

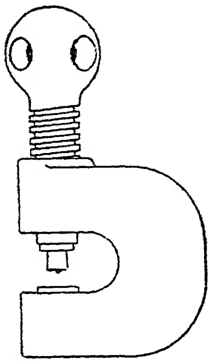


Fig. 42.—SCREW PUNCHING BEAR
Hydraulic types of similar shape are also employed.

contact of the fitting parts, therefore, soon results in compression and loosening.

Types of Cotters

Considerable variety is met with in forms and modes of application. Some are just a driving fit, to secure a rod into another part; others are locked by a split-pin or a side screw, while frequently the cotter has a screwed tail for this purpose. A cotter serves as an adjusting agent in connecting rods, drawing one brass against the other. By insertion of packing behind the brass, the distance from centre to centre may be kept constant, regardless of the effects of wear. When a forged strap embraces a rod end, the cotter requires a gib next to it to prevent the strap from spreading. Specimen fittings are outlined in Fig. 43.

Preparation for Fitting

Taking a common example, that of a crosshead attachment, the first duty is that of marking out the cotter-way in the rod. When machine-

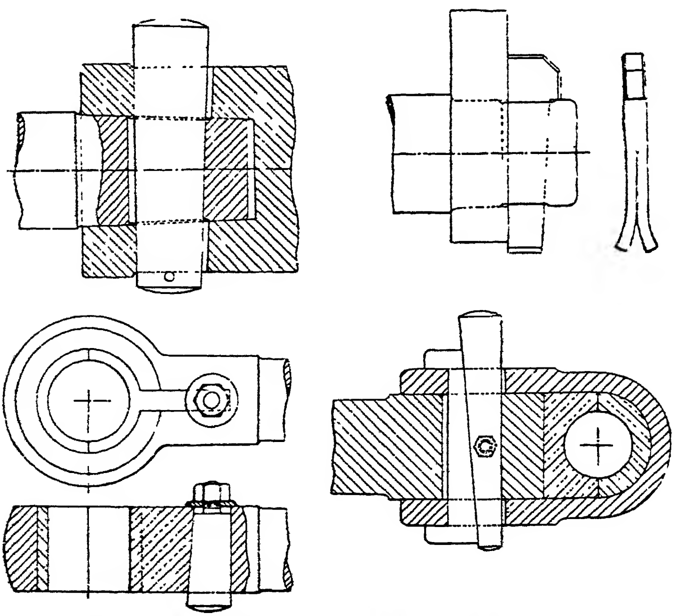


Fig. 43.—EXAMPLES OF COTTERS USED AS FASTENING AND ADJUSTING AGENTS

shop routine is so accurately arranged that all dimensions are worked to closely, the fit of the taper end of the rod in the crosshead can be depended on to bring the cotter-way a definite distance along in relation to the openings cut in the head. But for general production, the usual plan is to drive the rod into place, and then find the location for the slot by scribing through.

Chamfering

After slot-drilling, the surrounding metal each side should be chamfered to prevent burring, and consequent seizing in the crosshead.

Fitting Cotter Sideways

The cotter, already forged and ground roughly to outline, has to be filed on the sides until it will just slide without shake in the slots when the rod and head are apart. The bottom of the cotter is filed to the half-round contour, and tried in the head slots with redlead to test the accuracy of contact. If necessary, draw-filing is done to make the contact perfect.

Chapter II

INSTALLATION OF I.C. ENGINES

WHEN installing a heavy oil engine, the first problem to be tackled is that of lifting tackle.

Frequently the four main stanchions of the building can be arranged to carry the crane rails. If there is only one engine, however, and parts to be lifted do not exceed, say, 15 cwt., it is often a simple matter to support a girder along the centre of the room and arrange lifting tackle from this. Overhauling is sometimes provided for in this way when the plant comprises more than one engine, but in these cases it is not much more expensive to fit a crane of the hand travelling type, which will be generally more satisfactory in use. If tackle is rigged from a single girder, two men are usually required for the removal of pistons, etc., whereas a crane can be operated with ease by one mechanic. This point is worthy of consideration when deciding on the initial outlay of such an accessory.

Before the builder removes his scaffolding, his services should be enlisted to place in position any overhead water or fuel tanks, etc. It may be found an advantage to have these fixed before the roof is finished, and this work should then form part of the builder's contract and delivery of the tanks, etc., arranged accordingly.

Concrete Work to do at the Same Time

In proceeding with the work of excavating the foundations, it should be remembered that concrete supports for fuel and water tanks, exhaust pits, and pipe trenches should be made at the same time, and useful information on this subject will be given later.

ERECTION OF ENGINES

When the foundation work has been finished and all bricks, dust and dirt, etc., such as are usually connected with a building job, have been removed and the concrete has had a few days to harden, erection may commence.

Keep Engine Clean during Erection

At this stage it will, perhaps, be as well to give a few words on the subject of cleanliness. It is most important that any oil engine, or for that matter an engine of any sort, should be kept scrupulously clean whilst

Fig. 1.—TESTING LEVEL OF ENGINE WITH SPIRIT LEVEL

Any necessary adjustments for level are made by placing steel packing strips under engine.

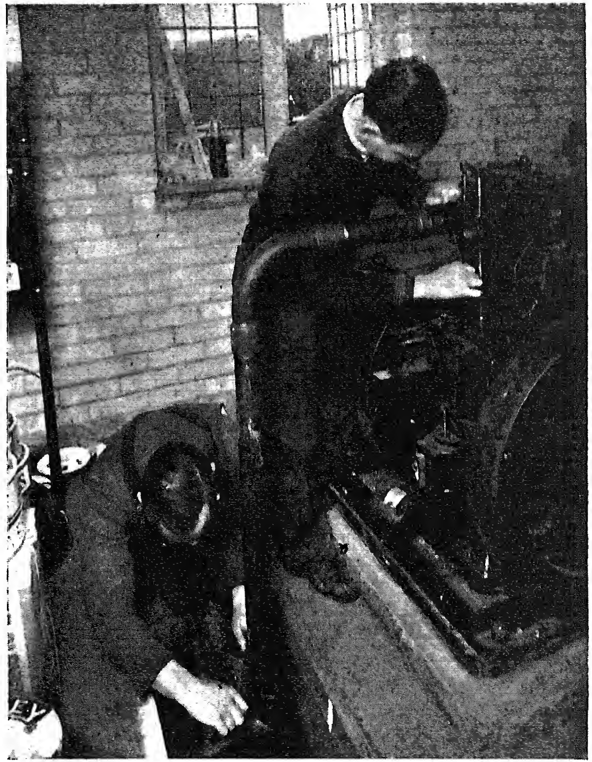


Fig. 2.—FITTING EXHAUST SYSTEM

This shows exhaust pipe being connected between engine and expansion box.

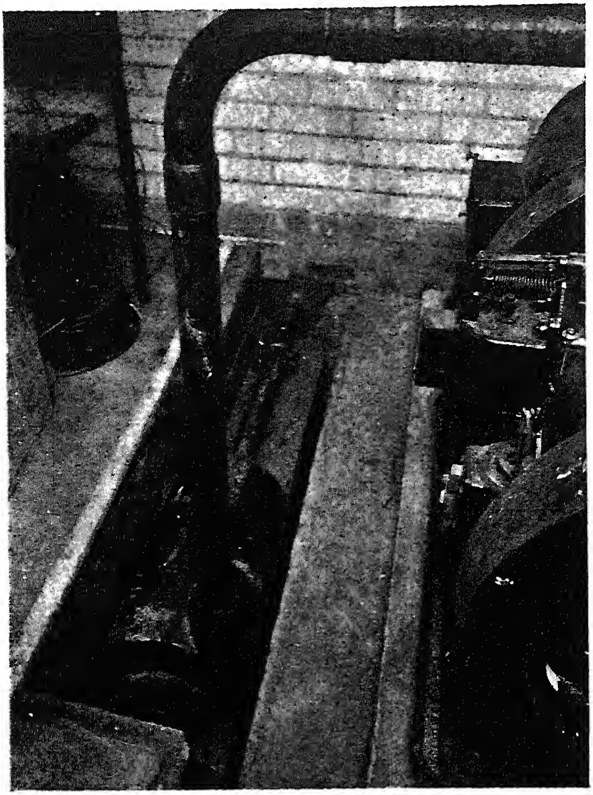


Fig. 3.—Showing layout of exhaust system

Note pipe going through wall into exhaust pit shown in the next photograph.

it is being erected, and care should be taken that no bearings or wearing parts go together with foreign matter between them. Given a clean engine, clean fuel oil, clean lubricating oil, and clean cooling water, sterling service can be expected from an oil engine, whereas dirt accumulated during erection may take years off the ultimate life of the engine.

Conveying Parts to the Site

It is usual for one door of the engine-house to be made sufficiently wide to allow for the machinery in its various parts to be either carried or rolled in. Where an extra wide doorway is provided, it may be possible to run the lorry close up to the foundation and slide such a part as the bedplate direct on to its base, thus saving a good deal of time. In some cases it may be advisable to leave part of the wall adjoining the doorway unfinished, so as to allow the lorry or trailer to enter.

Lowering Bedplate on to Foundation

If the lorry should happen to be higher than the foundation, timbers should be packed on the latter until the respective levels are the same, and the part can then be rolled on to the wood packing and gradually lowered by removing the packing piece by piece. Before the final packing is removed and the bed finally dropped on to the concrete, the wires which

are fastened to the foundation or holding-down bolts should be drawn through the bolt holes in the bedplate.

Placing Bolts in Position

When all packing has been removed, the bolts may be drawn up through the bolt holes by means of the wires, and the nuts screwed on until about one thread short of a full nut. In this way, when the nuts are finally drawn down tight, the bolts will not project through the nuts.

Now Check Position of Engine, etc.

The distance from the centre line of the crankshaft to the finished floor-level is now checked with the drawing, and the bedplate raised by means of steel wedges until this dimension is correct. At the same time dimensions from the centre line of the crankshaft to the wall, and from No. 1 cylinder to the wall, should be checked, likewise leading dimensions relative to other plant or machinery, and the position of the bedplate altered as may be necessary.

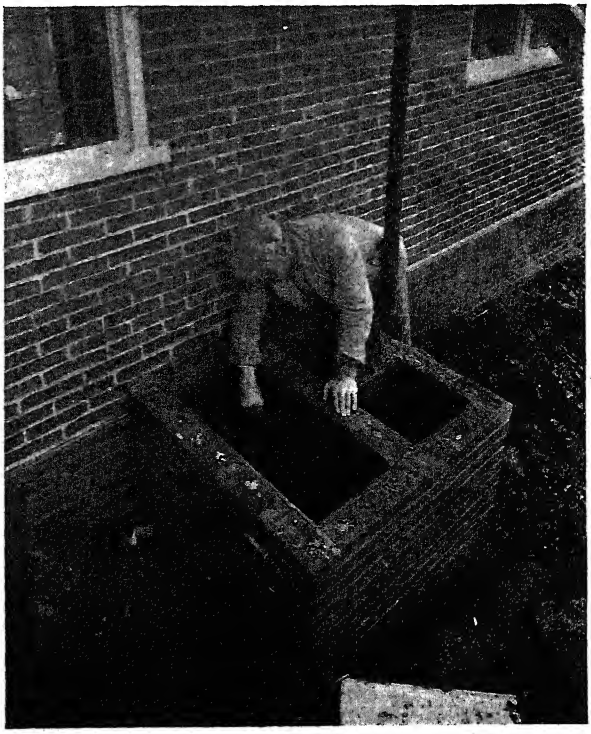


Fig. 4.—The exhaust pit

Walls of pit being rendered. End of exhaust pipe can be seen, also atmosphere pipe. Note that pit is divided into three sections.

Belt or Chain-drive Alignment

Where the engine has a belt or chain drive to existing machinery, the crankshaft should be placed in its bearings with pulley, etc., fitted and a line taken to ensure that the belt will run true on both pulleys.

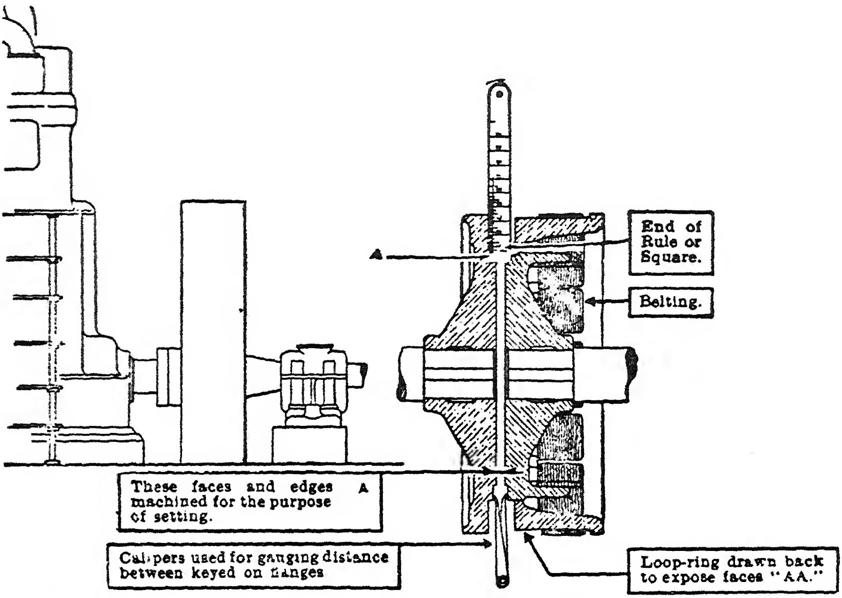


Fig. 5.—METHOD OF LINING UP FLEXIBLE COUPLING (*Ruston & Hornsby, Ltd.*)

Checking Direct-coupling Alignment

For checking alignment relative to existing plant to which the engine is to be direct-coupled, the respective half-couplings should be fitted and the faces brought to coincide. Feeler gauges will show whether alignment is correct.

Connecting Shafts by Flexible Coupling

Fig. 5 shows a method of connecting two shafts together by means of a flexible coupling, and on most types of coupling there are machined faces intended for use by the erector, which greatly facilitate the work of lining up. There is a tendency for erectors to be somewhat careless over this operation and to rely on the flexibility of the coupling itself to prevent trouble. Whilst most good flexible couplings are capable of dealing with reasonable errors in alignment, the shafts should be set in line as shown, and should be adjusted in line as far as practicable, in order to avoid undue wear of the belt and possible bearing troubles.

The actual procedure to be followed in lining up a flexible coupling will vary with different types and makes, but the question of correct alignment will always be important, and a method of checking can easily be devised to suit the particular make of coupling in question.

Grouting Bolts into Foundation Block

Flat steel packing pieces of varying thickness and of a length and width to suit the particular size of engine should be provided by the makers and a set put next to each holding-down bolt. The steel levelling wedges are then removed, and the bolts are then grouted into the foundation block to within, say, 6 in. of the top. The grout should consist of equal parts of sharp sand and Portland cement, mixed with water so that it flows freely.

Proceed with Erection of Tanks, etc.

Whilst the grout is hardening—and quick-setting cement will hasten this process—the erection of tanks and other accessories can proceed. There should be several days' work coupling up piping, etc., but the final position of the tanks, etc., is best left until the pipes are completely finished, thus avoiding any difficulties in mating flanges, which is sometimes apt to be difficult if working between two fixed points.

Next Step—Making Bedplate Level

As soon as the foundation bolts are fast, work on the engine must proceed, and other work must be left until the engine is properly grouted in. All the nuts can now be tightened up and a spirit level used in conjunction with a straightedge both longitudinally and across the bedplate.

Lining Up the Crankshaft

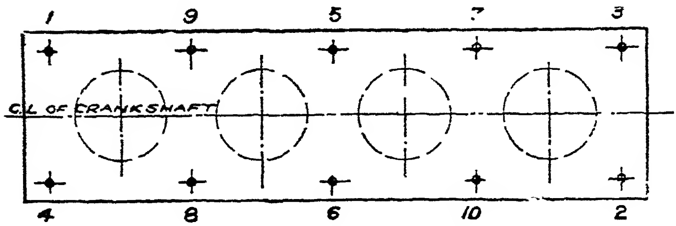
When the face of the bed has been made level by adjustment of the packing pieces at the various holding-down bolts, the crankshaft should be placed in position in the bearings, care being taken to see that all parts are thoroughly clean and that there is no dust or grit between the bearing shells and their housings. Particular attention should be given to the levelling-up process. If the makers are not erecting the complete installation or part of it, their services should at least be obtained if at all possible to check over the alignment of the crankshaft and bearings.

Method of Tightening Bedplate Nuts

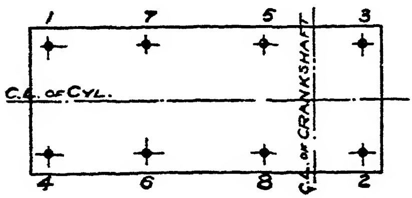
The bedplate nuts should all be tightened equally, that is, from corner to corner and across, as shown in Fig. 6. This is important on a multi-cylinder engine bed in order to avoid springing and to assist in lining up bearings correctly.

Testing for Loose Crank-journal Bearings

It is as well to go over the crank journals with a spirit level and to try tapping the bottom halves of the bearings to find the loose ones which are not taking their share of the weight of the crankshaft. The bearing shells



FOUR-CYLINDER VERTICAL ENGINE



(LEFT) SINGLE-CYLINDER HORIZONTAL ENGINE

Fig. 6.—CORRECT ORDER FOR TIGHTENING HOLDING-DOWN BOLTS

Bedplate nuts should all be tightened equally from corner to corner and across as shown above. This method avoids springing and assists in lining up bearings correctly.

should have been bedded into their respective housings at the works and each numbered, and care should therefore be taken to see that the bearings have not become misplaced from their correct positions.

Now Turn Crankshaft by Hand

With the top halves of the bearings tightened down evenly, the crankshaft, when lined up, should turn easily by hand.

If Crankshaft Runs Stiffly

If stiff, each top half should be inspected and scraped, if necessary, until free, and to give a running clearance as recommended by the makers, and determined by feeler gauges.

The bottom halves of the bearings should not be bedded to the crankshaft until all is done that can be done by levelling the bedplate proper. The makers will have previously run the engine on test and very little work should be required in this respect.

PLACING FLYWHEEL ON SHAFT

A Useful Tool for Erection and Maintenance

An easily made tool which is useful both in the erection and in the subsequent maintenance of the engine consists of a flat steel bar which can be secured to the crank web by two setscrews. This tool can be

clearly seen in Fig. 7, and it is a good plan to have a fitment of this sort provided by the engine-makers.

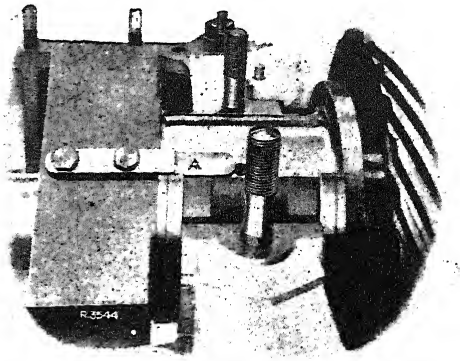


Fig. 7.—TOOL FOR REMOVING AND REPLACING CRANKSHAFT BEARINGS

The tool consists of a flat bar *A*, shown in position for removing bottom half-bearing. It is screwed to the crank web by two setscrews. To remove bearing, the crankshaft is turned slowly and the bar pushes the half-bearing to the top. This saves lifting the crankshaft and obviates any possible damage being done. (*Ruston & Hornsby, Ltd.*)

To Remove a Bottom Half-bearing

Should it be necessary to remove a bottom half-bearing at any time, the tool should be fitted as shown, and the crankshaft turned slowly with the bar in position, thus bringing the half-bearing to the top, whence it is easily removable for attention. This saves lifting the crankshaft and obviates the possibility of damage to crankshaft or bearing. Care must, however, be taken to see that the width of the bar is less than that of the bearing section, so that the shaft may be turned without jamming.

The flywheel should next be lowered into the flywheel race of the foundation and supported on timber packings whilst the extension shaft is brought close up and the bolts fitted.

Fitting Wheel to Crankshaft Coupling Face

When the wheel is being fitted to the crankshaft coupling face, care should be taken to prevent straining of the shaft by overhanging the weight of the wheel. The extension shaft should be supported by the outer bearing as soon as possible, so that the packing under the wheel can be removed. The same procedure applies if there is a dynamo shaft bolting up to the flywheel face, and in each case there should be shims, or liners, fitted to a total thickness of $\frac{3}{32}$ in. to $\frac{1}{8}$ in. between the outboard bearing and its sole-plate, in case future adjustment should be required.

Fitting Keyed-on Flywheel

If the flywheel is in halves or otherwise keyed on the crankshaft, extending in one piece to the outer bearing, then the latter can be fitted in position and its foundation bolts grouted in as soon as the bedplate and bearings are lined up. Generally, the quickest way of doing this is to place the sole-plate on the concrete pedestal, and to hang the bearing on

the crankshaft. The sole-plate is then packed up to the bearing, with packing pieces similar to those used under the engine bed, until the bearing is properly supporting the shaft ; the shims will, of course, have been fitted between the bearing and the sole-plate before placing in position.

The holding-down bolts can then be grouted in, in a similar manner to those for the main bedplate.

After allowing sufficient time to set, the nuts may be tightened down and the crankshaft alignment checked and corrected if necessary. The flywheel should then be fitted, and if this is in one piece it will be necessary to remove the crankshaft from the bedplate. This usually has to be done with the horizontal type of engine.

To Check Alignment of Complete Crankshaft

To check the alignment of the complete crankshaft is now necessary, and for this purpose a stick gauge is inserted between the crank webs and on rotating the shaft it is noted whether the webs open or close. A telescopic gauge can easily be made if not supplied with the engine, and will, in any case, be extremely useful for periodically checking over the crankshaft alignment.

Fig. 8 shows a line drawing of a multi-cylinder engine crankshaft, with exaggerated alignment fault. One can see from this that the crank webs of the throw, adjacent to a high bearing, will close when the throw in question approaches the bottom position.

Rectifying Non-alignment

The cylinder nearest the flywheel should be the first to have attention, and when the crank is on top dead centre, the gauge should be placed between the webs in the plane of the centre line of the crankshaft and adjusted to fit. The shaft is then given half a turn and the gauge tried between the webs. If slack, then the outer bearing is low, and it must be packed up slightly. If the gauge will not enter, then the packing of the bearing should be adjusted until the gauge is an exact fit in top and bottom positions. The horizontal alignment

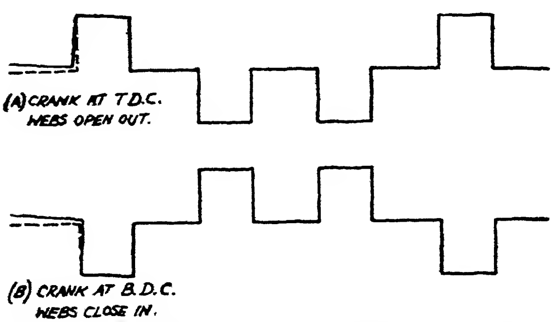


Fig. 8.—CRANKSHAFT WITH EXAGGERATED ALIGNMENT FAULT

Showing "breathing" of webs adjacent to a high bearing.

of the outer bearing should be checked in two positions, with the crank midway between top and bottom centres, and the bearing moved sideways until no breathing of the webs takes place.

On multi-cylinder engines the cranks should all be dealt with in turn and, when apparently correct, the whole shaft should be checked over to make certain that the adjustment to one throw has not interfered with that for the other cylinders.

Using Micrometer Dial Gauge

A spring-loaded gauge can be obtained which incorporates a micrometer clock. This gauge should be left between the webs and the plus or minus readings taken as the shaft is revolved. This type of instrument is sensitive and is easily used, and it is invaluable for showing at a glance the condition of the main bearings. The micrometer can also be adapted for measuring the clearances of the connecting-rod large- and small-end bearings.

The method of applying the dial gauge is shown in Fig. 9, which illustrates the method of testing clearances of both large- and small-end bearings.

Testing Shaft with Spirit Level

The crankshaft can also be tested for alignment with a sensitive spirit level, but it must be borne in mind that a slight allowance will have to be made for a deflection due to the weight of the flywheel. The level will read downwards towards the wheel both from the engine bearing and the outer bearing, the amount varying somewhat according to the distance of the centre of gravity of the wheel from the respective bearings.

Now Grout in the Bed

The bed can now be grouted in, and the space left when grouting the bolts will serve to form a key. A wall of clay or of wood of uniform height should be placed around the bed, to retain the grout, and this should form the finished level of the grouting. The grout must be stirred well underneath with a flat rod, and in the case of large engines the main grouting should extend over two or three days to give time for settling.

The outer bearing is similarly grouted in, but not until the grout in the bolt holes has finished settling. The finished level of the grout should be above the bottom of the bedplate and sole-plate, thus helping to make a good solid job.

Fitting Large-end Bearings to Crankshaft

The erection of accessories can now proceed once more. When the grout has sufficiently hardened to permit further work on the engine, the large-end bearings can be fitted to the crankshaft, after first making

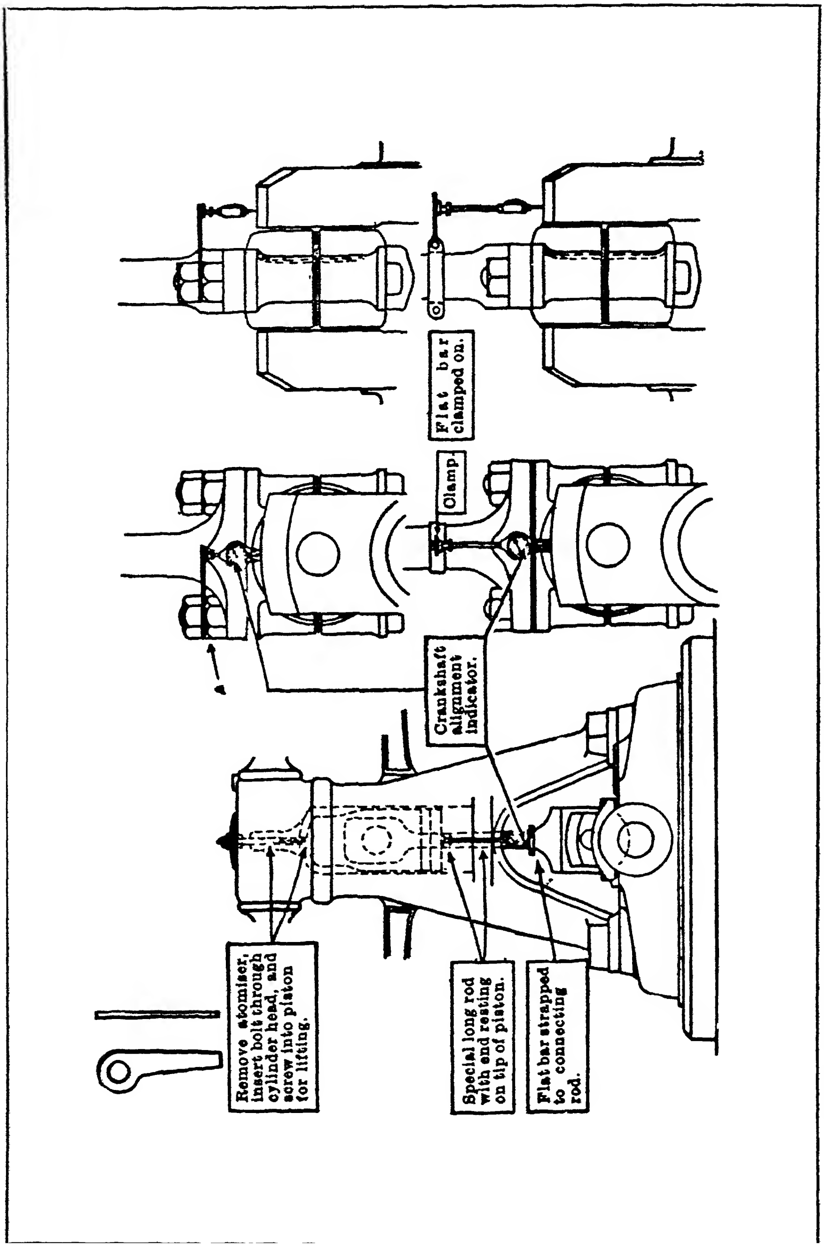


Fig. 9.—METHOD OF TESTING BEARING CLEARANCES WITH DIAL INDICATOR (*Ruston & Hornsby, Ltd.*)

sure that all parts are absolutely clean and that no foreign matter is contained in the oil holes of the crankshaft, etc. The crank journals should be well oiled and the oil wiped round by hand before the bearing halves are bolted together. The compression plates should have been stamped for each cylinder at the makers' works, and these should now be checked over and placed in position.

Fitting Connecting Rod

The housing and gear can now be assembled, and, in the case of a horizontal engine, the piston and connecting rod. To fit the latter, the rod is fitted to the piston and then slung as near to the skirt of the piston as possible and the piston pushed into the cylinder liner by means of the large end of the connecting rod. It will be necessary to adjust the height of the piston very carefully to permit entry to the cylinder skirt.

Arrangement of Piston Rings

All the rings should be well oiled and the gaps arranged so that they do not come in line, for this would cause loss of compression. The liner should be well oiled and oil wiped round the piston before assembling. When closing the rings so that they enter the liner, care should be taken that the edges are not damaged, which would cause scoring of the piston or liner.

Take Care to Prevent Breaking Skirt of Piston

Before lifting the pistons of vertical or horizontal engines, a block of wood should be wedged between the under side of the connecting rod and the piston skirt. If this is not done, the piston may fall back with the gudgeon pin as fulcrum and thus break the skirt. In the case of vertical engines the packing is taken out as soon as the piston is in the vertical plane.

With horizontal engines the packing is kept in position until ready to connect up to the large-end bearing. A piece of wood should be placed under the rod and rested on each side of the engine bedplate to take the weight of the rod. A length of pipe may be used for this, but there is a danger of it slipping forward towards the main bearings.

The back half of the large-end bearing is next mated up to the connecting rod and the bolts pushed through until the bearing half is held in position. The crankshaft is now turned so that the large-end journal is close up to the large-end bearing, the packing under the rod being adjusted so that the bearing half is in the path of the journal. The crankshaft can then be turned steadily until the journal touches the bearing, and the front half of this can then be bolted up and tightened. This procedure is reversed for removing pistons or large-end bearings and it is soon learned and quickly executed.

The same operation for a vertical engine is usually assisted by an eye bolt screwed into the piston crown, the cylinder head being, of course, removed, so that the piston and rod can be lowered into position from the top. For maintenance work it is generally possible to hold the piston in place by means of a bolt through the cylinder head whilst the large-end bearing is being removed.

To remove the piston and rod, the cylinder head is taken off and a bolt fastened in the piston, the large-end bearing is then disconnected and the piston and rod lifted out.

Care must be taken to see that the crankshaft is not turned whilst any bolts are fastened to the pistons, and it will also be necessary to see that the fronts of all rods are pointing to the front of the engine, for when the large-end connecting-rod bearings are bedded to the crankshaft journals they have to be lined up to the pistons, and to the small-end bearings, and this alignment may be lost if the bearings are reversed.

Erection of Valve Gear

The erection of the valve gear and camshaft, etc., can now proceed, and all brackets should have locating pegs, or else fitted studs or bolts to ensure correct alignment. Gear wheels which mesh will have the teeth stamped so that they can be meshed in the correct positions, and no mistake must be made here, otherwise the cam settings will be upset accordingly.

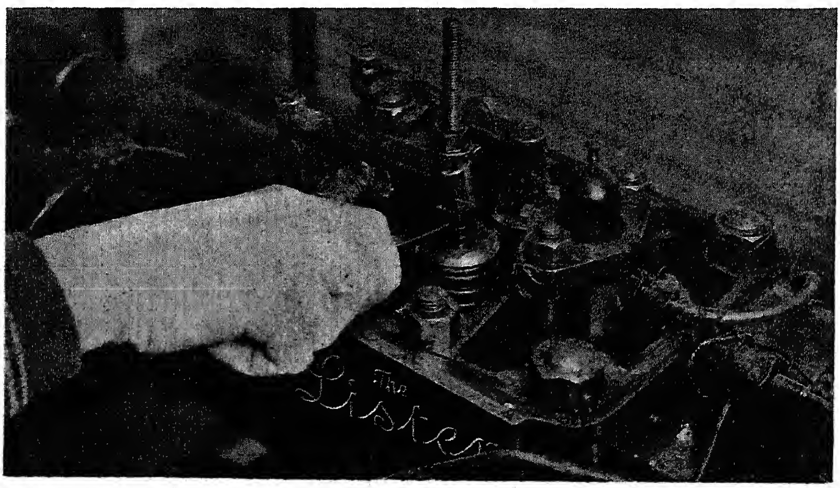


Fig. 10.—CHECKING VALVE-TAPPET CLEARANCES BEFORE RUNNING

This shows a Lister oil engine with inlet clearance of 0·017 in. and exhaust clearance of 0·032 in.

It cannot be emphasised too much that absolute cleanliness is essential in all stages of erecting and fitting major and minor parts. If the engine-house is not quite completed, all windows, doors, and openings likely to allow the ingress of dust and dirt should be blocked up with tarpaulins and sheets.

PIPEWORK AND TANK INSTALLATION

Pipework can now be permanently coupled up, screwed oil and water joints being made tight with hemp and a good jointing compound.

Cleaning Out Pipes

Pipes, other than oil pipes, should all be blown out with compressed air, if available, and during the erection of the engine they should have their ends protected from dirt and damage. Oil pipes should be cleaned out with paraffin before fitting.

Bend Pipes before Connecting Up

Pipes generally should be bent correctly before connecting up, in order to avoid strains on joints and flanges, etc., when the engine is running.

All pipes liable to expansion must be free to move.

How to Pack Exhaust Pipes passing through Wall

The exhaust pipes should be from 12 to 18 in. from any woodwork where they pass through the wall. It is advisable to pack the exhaust pipe in the wall with asbestos. To make a good job of this, bricks should be cut away to make a hole about 3 in. larger than the outside diameter of the pipe. Asbestos rope is then wrapped round the pipe to a thickness of about 1 in. and the remaining space grouted up with cement. This will permit expansion of the pipe, but the weight of the exhaust pipe and that of the exhaust manifold should be taken by means of roller supports.

Making Joints of Vertical Pipes

Very special precautions are necessary with the joints of vertical pipes, since these are liable to transmit vibration. Makers' drawings and instructions should be rigidly adhered to in such cases; for instance, in the case of a vertical pipe connecting on to the flat bottom of an overhead water tank, or any pipe requiring a water joint where it passes through a roof.

Carry Pipes outside Engine-room where Possible

Wherever possible, pipes should be carried outside the engine-room in a horizontal plane and should be amply supported.

Water Pipes—Drain Taps

Drain taps should be fitted at the lowest points of all water pipes and provision made for emptying the pipe trenches of oil or water, as previously mentioned whilst dealing with foundations.

Lagging Oil Line Exposed to Frost

If there should be a length of fuel-oil line from the storage tank above the ground and exposed to frost, it is a good plan to lag this with straw or other suitable material.

Except when the fuel storage is overhead, it is advisable to install a semi-rotary or other suitable type of pump to assist the flow of viscous oil and to remove air locks from the system.

Fuel-oil Tank—its Position

A usual position for the fuel-oil tank is immediately outside the engine-room, supported by brick or concrete piers, the bottom of the tank being about 1 ft. 6 in. to 2 ft. 6 in. above ground-level.

Oil-level Indicator

An oil-level indicator should be fitted inside the engine-room, and whilst this can be arranged for almost any position of the tank, it is as well to keep the arrangement of pulleys and gear as simple as possible.

When Tank is Underground

To economise in space above ground the tank or tanks can be buried underground, or else arranged in a pit with a suitably designed cover, fitted with a manhole so that a filling pipe from the wagon to the tank can be easily connected. Drainage of the pit should be provided for, likewise accessibility to pipe connections. The tanks should be well painted, and if to be buried and not enclosed in a pit they should be painted with special bitumastic paint. A fuel pump will be necessary in either of these cases.

Fuel Tank in Roof

The fuel tank can be arranged in the roof of the building, if this is suitably designed and sufficient space is available, but this is, as a rule, found more expensive than an outside tank. If, however, an overhead storage is decided on, then care should be taken that it is not so high that the fuel suppliers' wagons cannot pump to it.

Water-cooling Tanks—Test for Leakage before Installation

When several water tanks are supplied, as for the thermo-syphon system of cooling, each tank should be tested for possible leakage at the

seams owing to damage received during transit. If each tank is tested separately this saves loss of time and the trouble involved in disconnecting gear to rectify faults afterwards.

Piping Water from Pond or Sump to Jackets

With some systems of water cooling a pump draws water from a pond or sump and delivers it to the jackets. In these cases the suction pipe should have a gradual rise to the pump, otherwise airlocks may result if the pipe slopes towards the pump in any part of its length.

Piping to Cooler

If pumping hot water for delivery into a cooler, the length of suction pipe and the number of bends in it should be kept to a minimum, so that the total suction head, including friction, does not amount to more than about 10 ft. for a water temperature of, say, 150° F. Ten feet is not the maximum suction head allowable, but if exceeded it is possible that trouble may be experienced due to air bubbles, etc.; furthermore, the pump efficiency will be greater if the suction head is kept low.

A foot valve and strainer of approved type should be inserted at the end of the suction pipe.

Installing Fuel-service Tank

The fuel-service tank in the engine-room should not be lower than the dimension given on the maker's drawing, whilst a little extra height will not do any harm. Cocks and valves in the various pipes should be easily accessible.

Water Drain from Compressed-air Receiver

There should be a water drain in the compressed-air receiver, which is usually included in oil-engine installations for starting purposes. If not possible or convenient for this drain to be taken from the bottom of the vessel, then a simple arrangement is sometimes obtained by fitting the drain valve or cock at the top of the receiver and leading an internal pipe from this almost to the bottom of the vessel. In this way, when the valve is opened, any accumulation of water is forced out by the air pressure, and when such a valve is used a bent pipe should also be fitted to deflect the stream of water and air downwards, thus avoiding the possibility of this being sprayed about the engine-room.

Position of Air Receiver

The air receiver should be placed as near to the compressor as possible, at the same time in a convenient position for the attendant and close to the engine, with a valve easily accessible for starting-up purposes.

Fuel-oil pipes should, where possible, be run in the same trenches as the exhaust pipes and close to them, thus assisting the flow of oil.

PETROL-ENGINE LIGHTING SET

Foundations are the first concern, and these notes will also interest those concerned in the erection of the heavy-oil engine just dealt with, although, of course, the quantities and dimensions involved will be on a proportionately larger scale.

Stationary engines are usually mounted on a concrete base, and this should be from 6 in. to 10 in. above floor-level, according to size. It is the usual practice of manufacturers to provide a drawing with the engines they sell and this gives all the information necessary for the construction of the foundations.

A Typical Installation Drawing

An example of a typical installation drawing is given in Fig. 11. This shows a small single-cylinder petrol engine with its foundation, cooling tank, and exhaust silencer all set out to comply with the manufacturer's recommendations. The dimensions shown for the foundation are the minimum and are recommended on the assumption that the subsoil is normal. If this is of a loose and sandy nature, or waterlogged, the cross-sectional area and the depth of the foundations should be increased.

Concrete for Foundation

The best composition of the concrete for the foundation block is one part of Portland cement with four or five parts of washed ballast.

After the foundation is constructed, it should be allowed to stand for a few days before any attempt is made to start erecting the engine. In very hot or dry climates it is desirable to keep the foundation flooded with water during this period. The holes for the foundation bolts should be much larger than the diameter of bolts, to facilitate erection.

Erecting the Engine

The alignment of multi-cylinder engines on the foundation is a matter of extreme importance.

Lowering Engine into Position

The engine should first carefully be lowered to within about 1 in. of the concrete and allowed to rest on strips of steel about 8 in. long, 2 in. wide, and of varying thickness. These strips or packing pieces should be near the foundation bolt holes, and the engine should be levelled by the insertion or removal of strips until it is perfectly level, when the foundation bolts can be grouted. After an interval of a day or so, the concrete

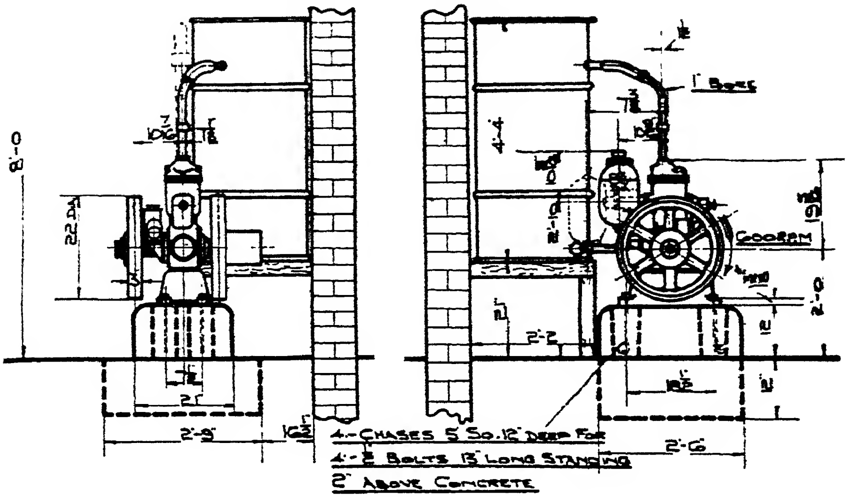


Fig. 11.—TYPICAL INSTALLATION DRAWING OF 5 B.H.P. PETROL ENGINE—SIDE AND END ELEVATION

in the bolt holes will have set, and the nuts on the bolts can be pulled down tightly.

Levelling Bedplate

The level of the bedplate should then carefully be tested with a spirit level. If any deflection is observed, the inequality must be corrected by the removal of some of the packing strips until the bedplate is level at all points.

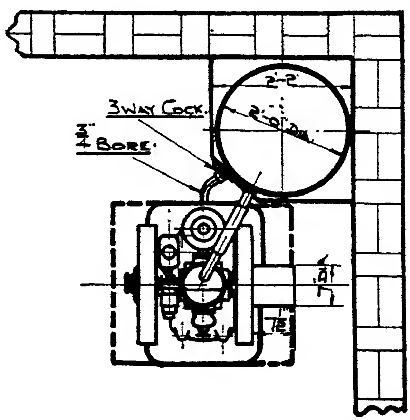


Fig. 11A.—PLAN OF TYPICAL PETROL-ENGINE INSTALLATION

Final Grouting

When this stage is reached the foundation can finally be grouted up with a composition of two parts of fine sand and one part of cement.

Arrangement of Belt Drive

If the engine is to drive by belt on to fast and loose pulleys, these should be arranged in such a way that when driving on to the fixed pulley the belt is near the engine

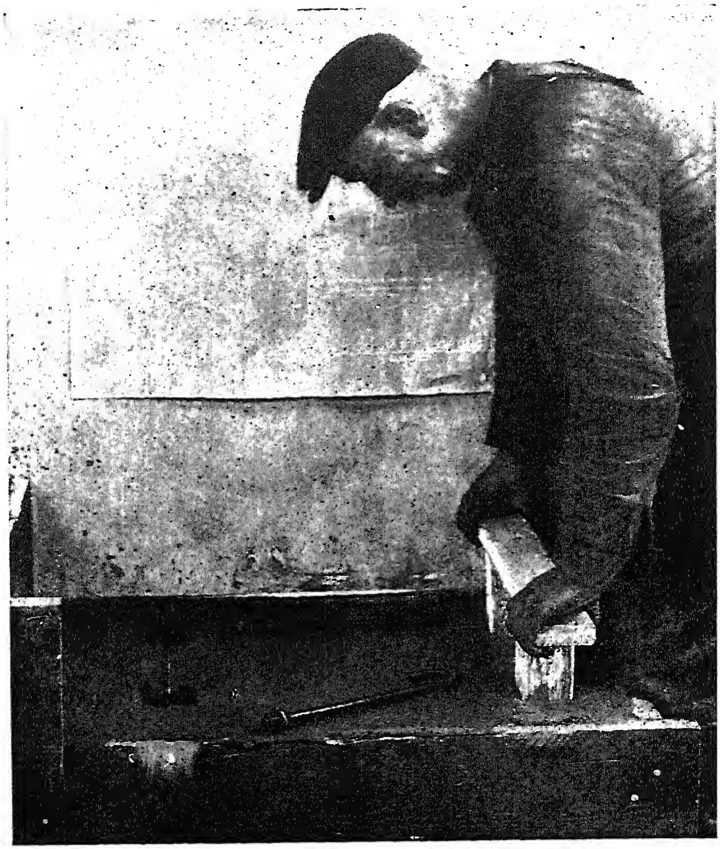


Fig. 12.—MAKING CONCRETE FOUNDATION

Withdrawing the formers which make the holes for the holding-down bolts. The formers are tapered slightly for easy withdrawal. They are drawn out before the concrete has set hard.

bearing. This applies particularly when the engine pulley is overhung, e.g. when there is no outboard bearing.

The under side of the belt should be the driving side whenever possible as the arc of contact is thereby increased by the sagging of the slack side. The pulleys should be arranged to give a belt speed of about 3,500 ft. per minute, and care should be taken that the belt used is capable of transmitting the necessary power. The life of a belt will be prolonged and its driving powers increased by keeping it in good working order.

Direct Coupling

It frequently happens that engines are to be directly coupled to some other machine such as a dynamo, pump, or air compressor, and that such machines are not mounted with the engine on a combined baseplate. In such cases, the procedure outlined above for engine levelling should be applied to the machine which is to be driven.

Aligning Direct-coupled Shafts

Should the driven machine be rigidly coupled to the engine, it is of the utmost importance that the shafts of both should be in the same

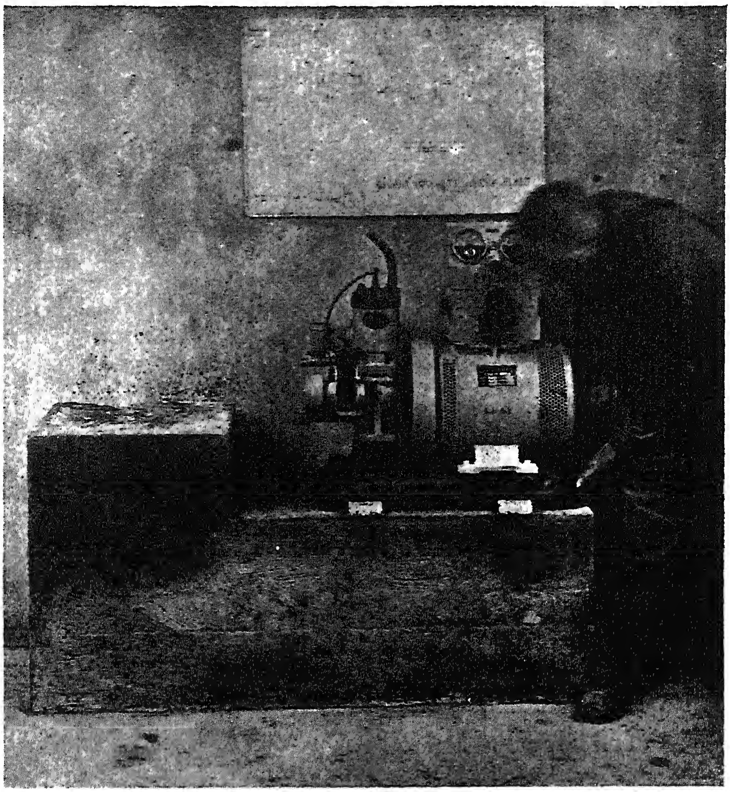


Fig. 13.—Placing petrol-engine lighting set in position on concrete bed

This shows the plant being lowered on to two strips of wood. Note that the holding-down bolts have been inserted through the bedplate, and the nuts screwed on. The next step is for the bedplate to be made level by the aid of steel wedges or packing pieces of varying thicknesses.

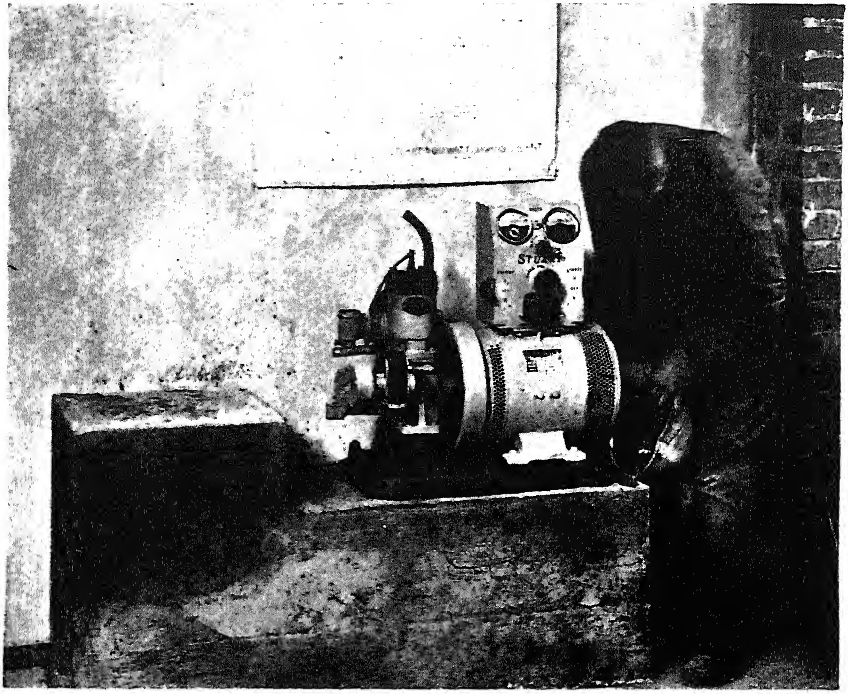


Fig. 14.—GROUTING-IN THE PETROL-ENGINE LIGHTING SET

Filling up bolt holes with liquid cement after bedplate has been made perfectly level. If the bolt holes do not show, a small channel leading into them should have been scraped in the top of the bed. After the holes have set, the nuts on the bolts can be tightened and the bedplate again be made level, and finally be grouted up.

horizontal plane in order to prevent mal-alignment. If they are not, there is a danger of the crankshaft fracturing due to fatigue set up by the alternating stresses generated.

How to Test for Correct Alignment

To obtain correct alignment, the two halves of the coupling should be brought together and a feeler gauge inserted between the coupling faces. If the same reading is obtained at intervals of 90° round the coupling, the bolts can be tightened up.

Usual Flexible Coupling

If a flexible coupling is used, the results of mal-alignment will not be dangerous, but even so the stresses have to be absorbed at some point, and the same care should be taken to ensure correct alignment.

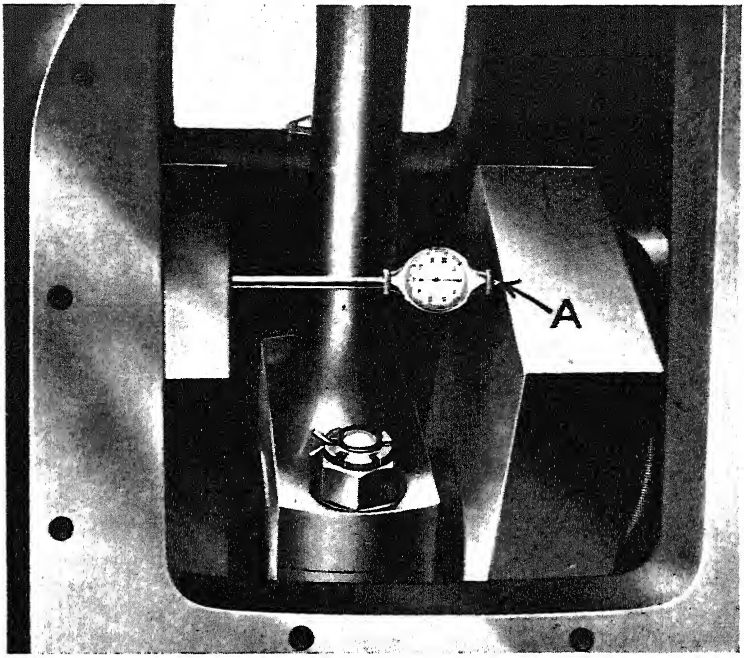


Fig. 15.—Testing alignment by means of an alignment indicator

This shows a check being made on alignment of two connected machines by inserting indicator between webs of crankshaft and noting readings at intervals of 90°. Adjustment of indicator is effected from end marked *A*.

Checking by Means of Alignment Indicator

When the two machines are finally connected, the alignment should be checked by means of an alignment indicator. This simple instrument can be bought for a fraction of the cost necessary to defray the cost of a new crankshaft, particularly if the engine be of medium or high power. The check is made by inserting the indicator between the webs of the crankshaft and noting the readings at intervals of 90° (see Fig. 15).

Mal-alignment will be most noticeable between the webs nearest the flywheel, and a difference of 0·002 in. should be investigated and corrected.

Check Up Alignment Periodically

It is a commendable practice periodically to check the alignment because the foundations may subsequently settle, and disturb the position of the engine and driven machine sufficiently to produce serious mal-alignment. The importance of correct alignment will be appreciated

when it is remembered that if the engine speed is 800 r.p.m. there are 384,000 alternating stresses in a running period of eight hours.

Cooling Equipment

Most stationary engines are cooled by the tank thermo-syphon system, and this is an excellent system in all cases where there is no objection to space which the water tank or tanks must occupy. If the water tanks are not supplied by the engine manufacturers, the user should be advised by them regarding the required capacity. For normal conditions a capacity of eight or ten gallons per B.H.P. of engine power is usually allowed. If the engine is working continuously for long periods, or is installed in a tropical climate, this capacity should be increased by 50 to 100 per cent.

Installing Thermo-syphon System

In a thermo-syphon system, the water tank should preferably be installed out of doors and the top of the tank should be well above the top of the engine. The size of water piping should be that recommended by the manufacturers, and the pipe connecting the engine outlet to the tank should have a gradual rise. The water in the tank should always be above the pipe from the engine, otherwise the circulation will cease unless the natural thermo-syphonic action be assisted by a water pump. If there is no pump in the system it is desirable to connect the main supply to the tank, and fit a float valve to maintain the level.

"Run Through" Cooling System

If there is an ample supply of water available, water tanks need not be used, as the water can be allowed to run through the engine to waste. This is known as the "run through" system, and when used the water should be available at a pressure of not less than 10 lb. per square inch, which is equal to a head of about 20 ft. With this system, from 1½ to 3 gallons of water per B.H.P. hour are required, according to the temperature of the water being used.

Dealing with "Hard" Water

In some localities the water is "hard"; e.g. contains much mineral deposit held in suspension. Such water will deposit lime if its temperature when leaving the engine exceeds about 150° F. This precipitation in the water spaces rapidly reduces their area, and consequently the engine "overheats." The remedy is to remove the scale from the water spaces and increase the velocity of the water to reduce the temperature rise.

Radiator Cooling

Some engines are cooled by a radiator similar to the motor-car, and usually the circulation is assisted by a water pump. If there is no pump,

the water in the radiator should be at a higher level than the top water pipe.

Disposal of Exhaust Gases

The disposal of the exhaust gases is a matter about which some care must be taken. The piping should be as short as possible, and the atmosphere end of the pipe should be fitted with a bend or cowl to prevent the rain from running down the pipe to the engine.

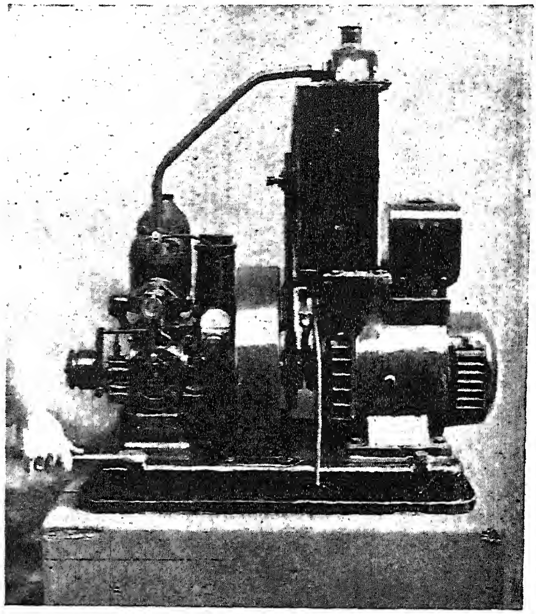


Fig. 16.—Finally pulling down foundation bolts after grouting

The plant is a small radiator-cooled lighting set.

Silencing the Exhaust

In thickly populated areas, the exhaust should be well silenced, and in such cases the use of an auxiliary silencer or pit is recommended. If the bore of the exhaust piping is too small, back pressure will be set up and this is detrimental to the engine.

The bore of the piping should not be less than that recommended by the engine builders.

Fuel Tank

Most stationary engines have a gravity-feed fuel supply and the fuel tank should be slightly above the level of the carburettor in order that there may be a good head of fuel at the delivery point. The fuel tank should be fixed in an accessible position and where there is no likelihood of water reaching the fuel.

THE INITIAL START

Tighten all Nuts and Joints

After the engine has been erected and the piping connected, all the external nuts and piping joints should be tightened down before the initial start is made.

Fill Water and Fuel Tanks and Lubricator

The water and fuel tanks should be filled, and the lubricator should be filled with the correct grade of lubricating oil. The engineer should go round the engine with an oil can to fill up the sundry oil holes; and if the main bearings are ring-oiled the oil wells should be filled up to the correct level.

Test for Obstructions

The engine should be given a few turns by hand, with the compression cocks open, to ensure that there are no obstructions. It is wise to make sure that the water is reaching the cylinders, and that there are no obstructions in the piping. The lubricating pipes should be primed and care should be taken that these pipes also are free from obstructions.

Set Lubrication Going

If the lubrication is of the drip-feed type, set the drops per minute to the figure recommended by the manufacturers.

Turn on Fuel

Turn on the fuel and lightly flood the carburettor.

Switch on and Start

Switch on the ignition, and if the engine is of the hand starting type it should start after a couple of turns.

Tighten Joints

When it is "away" let it run light for a time, and after it has "warmed up" go round the engine again with spanners and pull down all bolts and joints tightly. It is frequently found that joints exposed to heat will need tightening when the engine is thoroughly warm.

The "Tune" of the Engine

A mental note of the "tune" of the engine should be made. An engineer skilled in the management of petrol engines can, simply by noting the "tune," say if the engine is running well, and it is surprising how quickly anyone can acquire the habit of listening critically to an engine. The sounds it makes when running are a reliable guide to its performance.

Faulty Engine

It has been so far assumed that the engine started easily and quickly, and this should be the case with a new engine, although there are exceptions. If a start is not effected after a few smart turns, it is a waste of energy to continue to crank the engine and hope for the best. The more intelligent method is to look round and locate the reason.

Chapter III

INSTALLATION OF BOILERS

PROBABLY the factor uppermost in the engineer's mind when handling a boiler on site for the first time is the lack of cranes or other lifting tackle such as he is accustomed to in workshop practice. When it is considered that a Lancashire boiler 30 ft. in length and 9 ft. in diameter, suitable for a working steam pressure of 200 lb. per square inch, may weigh over 40 tons when stripped of its fittings and empty of water, it will be realised that the absence of power-driven lifting tackle adds much to his labours. If, however, he will provide himself with suitable timber packings, jacks, levers, rollers, wedges, and chains or ropes, as mentioned later, he will find that by the exercise of a little patience, he can handle with ease and safety the largest Lancashire boilers made, and take a pardonable pride in his achievement.

It cannot be too strongly stressed that it is false economy of time and energy to attempt to move a Lancashire boiler without adequate tools, and while these may involve a little extra expense, they are worth it. In a good number of cases, it is possible to borrow these tools from a neighbouring works at a small cost.

Determining Required Strength of Lifting Tackle

A table is given below showing the average weights of the standard sizes of Lancashire boilers for various steam pressures, and from this it will be possible to determine the strength required in the lifting tackle. Generous margin should be allowed to provide for contingencies.

APPROXIMATE WEIGHT OF LANCASHIRE BOILERS IN CWT.

	Pressure				
	100 lb.	125 lb.	150 lb.	180 lb.	200 lb.
20′ × 6′	165	175	195	235	255
22′ × 6′ 6″	195	210	246	290	310
24′ × 6′ 6″	210	230	270	325	340
28′ × 7′	240	270	340	390	430
30′ × 7′	260	285	360	420	500
30′ × 7′ 6″	290	325	400	470	520
30′ × 8′	350	405	450	503	560
30′ × 8′ 6″	408	448	512	600	700
30′ × 9′	434	500	583	670	810

Tackle for Normal Installation

In a normal installation where the ground round the site is for practical purposes level, no steadying chains or ropes will be necessary, and two lifting jacks of either the screw, ratchet, or hydraulic type, together with one traversing jack, will be ample.

The Jacks—their Purpose

The lifting jacks will raise or lower the boiler in the vertical or approximately vertical plane, and the traversing jack, while carrying the weight, will enable the boiler to be moved in the horizontal plane. This latter jack is used for slewing the boiler round corners or turning it end for end, and, if the approach to the boiler settings is clear and open, may not be required.

Points to Remember when Planning Route of Boiler to Site

It will be obvious from the shape of a Lancashire-type boiler that, unless carried on wheels and undergear with swivelling axles, it will be more easily moved in a straight line in the direction of its length or rolled in a direction at right angles to its length. These directions should therefore be kept in mind when planning the route for the boiler, and any path of travel oblique to these directions or on the slant should be avoided wherever possible. Similarly, when raising or lowering a boiler into the desired position, this should be done as vertically as possible and not on an inclined plane.

With these general and preliminary remarks we are now in a position to consider concrete examples of handling a Lancashire boiler.

An Example—Boiler Delivered at Site on Rail or Road Wagon

The first case to be taken is that in which the boiler is delivered at or near the site on a railway or road wagon. This wagon will be of the open type with the boiler resting on timbers and wedges securely chained or roped down.

How to Take Off Boiler from Wagon

The relative position of the boiler-house will decide whether the boiler must be rolled off the truck sideways or taken off in the direction of its length. In the former case a staging of timber baulks should be erected level with and as close to the truck as possible, of sufficient length to carry the boiler, and in width preferably not less than twice the diameter of the boiler. This width will enable the boiler to be rolled well clear of the truck, which will then be available for other work. Fig. 1 shows the timber staging.

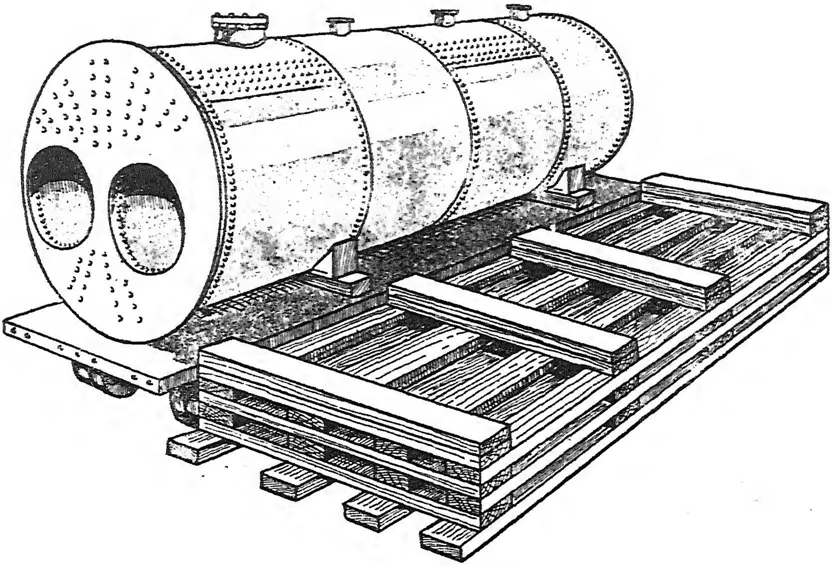


Fig. 1.—TIMBER STAGING FOR REMOVAL OF BOILER FROM ROAD OR RAILWAY WAGON

Note the timber baulks placed at right angles to the truck. The baulks on the top layer are in two, in order that when the boiler is rolled on to the staging its projections will clear the timber.

The Timber Staging

The actual ground space covered by the staging will depend on the nature of the ground and its capability of carrying the load placed on it. It is advisable that no part of the staging should encroach or rest on the truck, as this will hinder the boiler being lowered to ground-level. It will now be apparent why the staging should be placed as near the truck as possible, and to avoid any tilting of the staging the timbers first receiving the weight of the boiler should not overhang. It is not generally necessary to bolt or lash the baulk of timbers together.

Method of Rolling the Boiler

The rolling of the boiler can now begin, and this should be done patiently and with caution, taking no steps of which the consequences are uncertain or the extent undefined.

With a lifting jack under the vertical centre line at each end of the boiler raise the boiler slowly an inch above its previous level, keeping the wedges close to the boiler shell to prevent any side movements. With the wedges on the off side remote from the staging driven close under the boiler shell, remove the wedges on the near side an inch or so

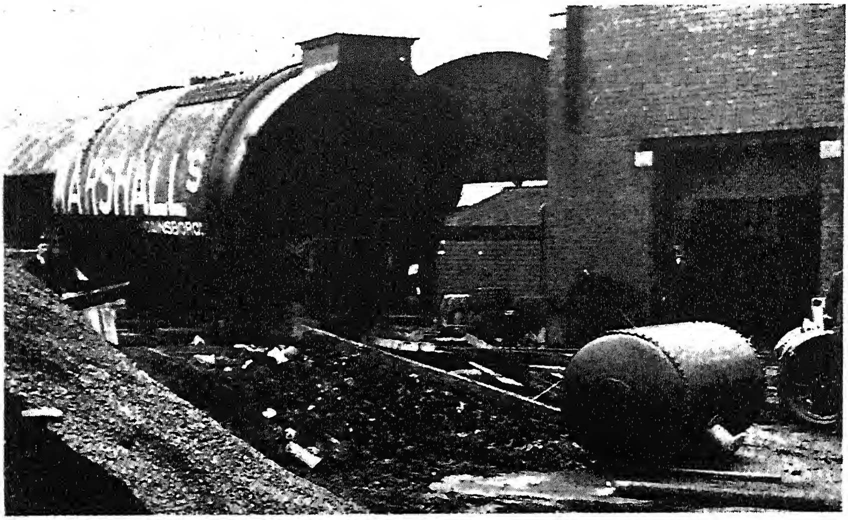


Fig. 2.—Return-tube boiler being moved into house on right

One of the traversing jacks can be seen below the left-hand flue.

away. By slowly lowering the jacks supporting the boiler it will be made to roll slightly on the off-side wedges before coming to rest again on the truck timbers, the near-side wedges being kept handy to keep the rolling movement under control.

Again, with the boiler in its new position, lift it slightly with the jack, drive in the off-side wedges, bring the near-side wedges towards the staging, and once more slowly lower the boiler down. This will add a further slight turn to the boiler, and by repeating this procedure the necessary number of times, depending on the diameter of the boiler, it can be turned over off the truck on to the staging.

Care when Rolling Boiler

The amount of turning movement at each lifting and lowering of the boiler will of necessity be very small, but this is advisedly so, considering the weight being moved.

The timbers forming the top layer of the staging should be at right angles to the length of the boiler, and so placed that they do not foul the projections from the boiler shell, such as the standpipes for the stop valve and safety valve, during the rotating movement.

The above method of revolving the boiler can, of course, be used at any subsequent stage in the handling of the boiler to level it up prior to placing it on the settings.

Lowering Boiler to Required Level

We have now got the boiler clear of its truck, and it is the first duty of the engineer in charge to get it as near to ground-level as is convenient for its further movement. Keeping the boiler at any height above that absolutely necessary involves additional staging and the possibility of unwarranted risks.

The process of lowering the boiler to near ground-level is simple if done slowly and with care. With a lifting jack under the vertical centre line at one end of the boiler, lift it until it is just clear of the timbers. Remove the top layer of timbers, except those carrying the weight at the other end. Lower the boiler down slowly until it comes to rest at the jack end on the second layer of timber baulks. The boiler now slopes down slightly to one end, but if the staging is firm and rigid it will take no harm. Repeat the process again at the other end of the boiler, removing this time two layers of timber, if these are not of too great a depth to cause a dangerous tilt. The boiler will now slope in the opposite direction to that just indicated, and by jacking at alternate ends and removing the supporting timbers can be lowered ultimately to the required level. It will be obvious that if at any later stage the boiler requires to be lifted again to a new level, the operations just described can be reversed.

The above procedure for rolling is that recommended when the boiler is at a height above ground. Each movement is small and under control, and no avoidable risks are run. The work can be done by only two men, though three are an advantage for speed in shifting the gear.

Method of Rolling when Boiler is At or Near Ground-level

When the boiler is at or near ground-level, another and faster method of rolling can be employed, but more men and a couple of hand winches will be required. After making a suitable timber track for the boiler to roll on, the two winches should be anchored down some distance beyond, but in line with the boiler and its direction of travel. A wire rope is attached to the base of each winch, run along the ground under the boiler, brought round over the top of the boiler, and then back again to the winding drum.

By winding the rope in, it will be seen that the boiler can be revolved the whole of its travel without resetting any of the gear. Wedges behind and in front of the boiler should be moved along with it to control the movement. This method is very useful in cases where the boiler has been floated by water to its destination, and has to be hauled up the sea-shore or bank of a river. The timber track carrying the boiler should have its top face about 18 in. above any supports, so that the standpipes and projections from the boiler shell clear the ground during rotation.

Engineers abroad may find it more convenient to substitute for the

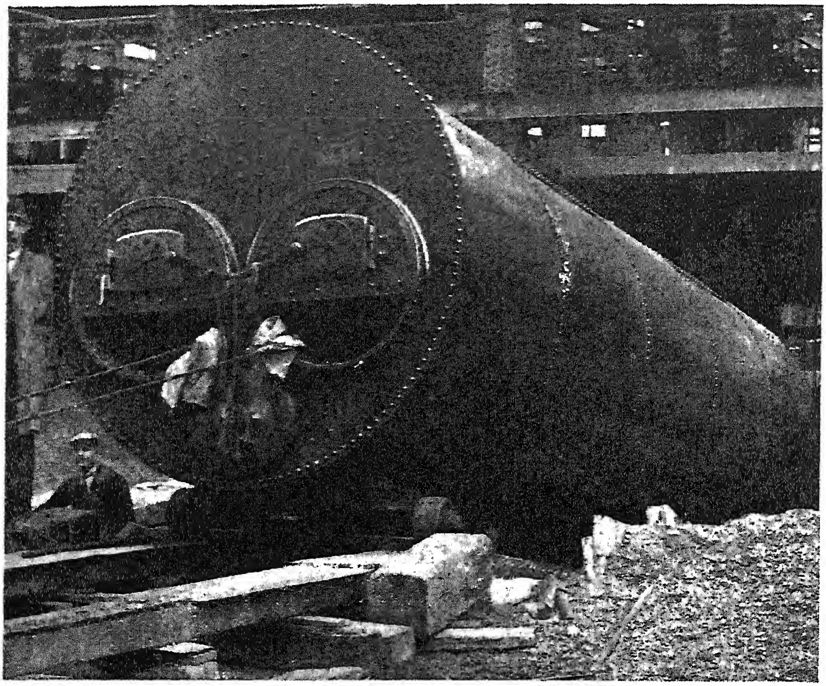


Fig. 3.—LOWERING LANCASHIRE BOILER ENDWISE
Showing the kind of timber track used for moving a boiler.

winches a gang of native labour, a team of mules or oxen, and, in India, possibly an elephant, but the principles of the operation remain the same.

Moving Boiler Endwise from Wagon

We will now return to the problem of moving a boiler off its rail or road wagon when the boiler, instead of being rolled off, is drawn in the direction of its length. The methods of doing this fall broadly into two categories, depending on whether sufficient motive force is available to pull the boiler bodily along, or whether this must be done intermittently by the use of jacks.

Using Rollers

In either case some system of rollers must be introduced under the boiler to allow it to move. In their simplest form these rollers would be cylinders of hard wood, such as straight pieces of tree trunk not less than one foot in diameter and long enough to cover the track on which the

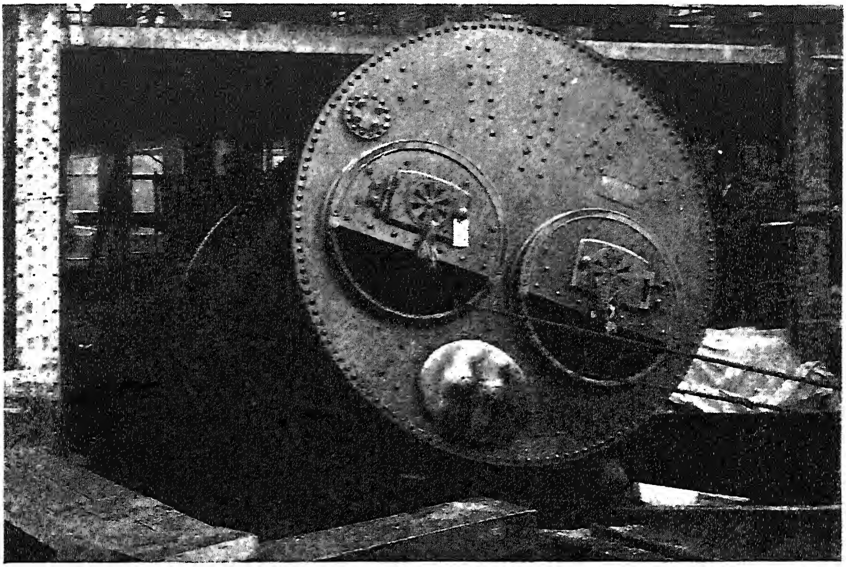


Fig. 4.—Lowering Lancashire boiler down an incline on wheels
The steel ropes pass down each flue and are attached at the back end.

boiler is to be moved. Many boiler manufacturers keep suitable rollers in stock for loan to their customers. Another form is a very low trolley fitted with travelling wheels, specially made, of course, for the job ; but as these trolleys will not generally be available to the plant engineer, we will confine our attention to the rollers mentioned above.

First Jack Up Ends and Place Rollers in Position

The front end of the boiler, then, is jacked up high enough to allow a roller to be inserted under it at right angles to its length behind the blow-off fixing, the roller being supported by the timbering underneath. Wedges will be kept on either side of the boiler between the boiler and the timbering to prevent it rolling sideways. The other end of the boiler is now jacked up and a similar roller placed under some distance from the end. A third roller may also be used at about the middle of the length of the boiler.

Hauling Boiler, using Power

If winches are available, or a tractor with winding drum, or some equivalent, a strong wire rope is passed down the entire length of each flue and firmly lashed to timbers or steel joists which straddle the flues.

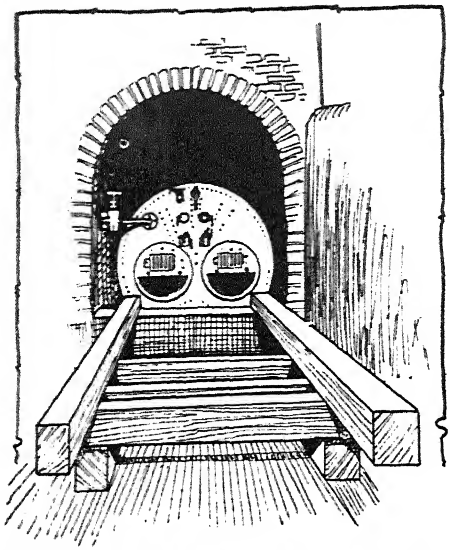


Fig. 5.—Suitable timber track over which boiler is moved into position

The other ends of the wire ropes are attached to the winding drum, or whatever motive power is being used, and placed in the line of travel, and the boiler can now be hauled forward bodily.

The movement should be slow and the wedges kept close to the shell to prevent rolling. Wedges may also be placed in front of the rollers to check any lurching. The staging erected to receive the boiler will be similar to that already described, with the exception that the top layer of timber will lie in the direction of the length of the boiler.

Hauling Boiler, using Traversing Jack

If the hauling power assumed above is not available, the traversing jack will serve the same purpose, although the movement will now be intermittent and slower. The jack in its back position of traverse is placed under the rear end of the boiler and jacked up to take the weight. By now working the traverse into its forward position the boiler can be moved along its path a distance of probably 6 in. or so. The jack is then let down so that the boiler comes to rest on the rollers and the traverse is brought again to the back position. By taking the weight of the boiler once more and bringing the traverse forward the boiler is moved a further stage, and this process is repeated until the truck is cleared.

Hauling Boiler, using Lifting Jack

If the engineer has no traversing jack, an ordinary lifting jack can be used by inclining the jack about 30° from the vertical and leaning towards the boiler. The head of the jack is brought on to the rounded portion of the back end-plate, and by slowly taking the weight the boiler can be pushed forward a few inches at a time.

How to Move Boiler Round and Sideways

Any of the methods just described can, of course, be employed at any subsequent stage of the proceedings. With the traversing jack taking the weight at one end of the boiler, but this time with the traverse working

across the boiler, that end can be slewed round a few degrees at a time to make the boiler point in any desired direction, such as would be necessary when going round a corner. By using this method at alternate ends the boiler can be moved bodily sideways without rolling.

It has now been demonstrated how the boiler can be rolled sideways, raised or lowered, moved forward in the direction of its length, slewed round into any new direction, and moved bodily sideways without rolling.

A combination of some or all of these movements will ultimately bring the boiler to a position where it is ready to be placed on its settings, and a description of these settings will now be given.

BOILER SETTINGS

It will make this description clearer if we regard the settings as the brickwork which supports, and which forms the external flues, of the boiler, and the foundations as the concrete raft or other masonry structure which, in turn, carries the brickwork.

In practice, the expressions for the boiler settings and the foundations carrying the brickwork are frequently used without distinction.

Design of Settings for Lancashire Boilers

In the settings for Lancashire-type boilers, there are three flues formed by the brickwork external to the boiler. The main flue is directly underneath the boiler, and is formed by the two walls which carry the weight of the boiler. The other two flues lie one on each side of the boiler. These are shown in the cross-section, Fig. 6.

Dimensions

It will be clear that the overall dimensions of the settings will vary, depending on the size of boiler being installed, and it is common practice for the manufacturers to supply a complete drawing to suit each case. As a guide, however, it may be said that the height of the two side walls of the main flue is generally about three feet to the top of the seating blocks, and that the width of the main flue is half the diameter of the boiler.

The width of the side flues should not be less than 12 in. at the narrowest part, as it is necessary for a man to pass down these flues for cleaning out, and for inspection of the boiler plates.

The height of the side flues is such that the lowest water-level in the boiler is above the top of the flue. This ensures that at no time during the working of the boiler are the hot gases in the side flues in contact with plates bared of water.

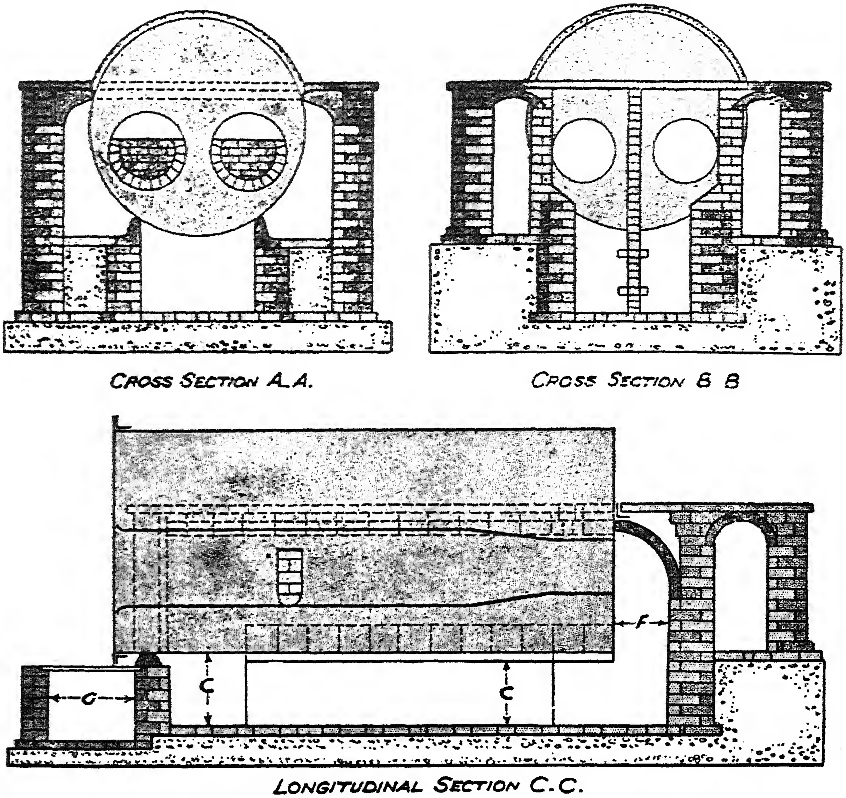


Fig. 6.—SETTING OF LANCASHIRE-TYPE BOILER—CROSS AND LONGITUDINAL SECTIONS

Passage of Hot Gases and Damper

In a normal installation, the hot gases from the furnace pass along the internal flue or flues of the boiler, drop down at the back end into the bottom flue, pass along this to the front of the boiler, where they divide into the side flues and away along these to the chimney. A damper is provided in each side flue at the back end to regulate the draught. Two cast-iron inspection doors are usually provided in the outer walls of the settings to give access to the flues. The front or firing end of the boiler is always $1\frac{1}{2}$ or 2 in. lower than the back end, so as to tilt the boiler upward towards the chimney to assist the draught and to facilitate emptying the boiler.

All sharp corners or rapid changes in direction of the passages for the flue gases should be avoided, as they impair the draught.

Laying the Foundations

Excavations must be made until solid ground is reached, and a concrete raft not less than 12 in. thick constructed over the whole area covered by the settings and surrounding flues. The raft should be without joints and may with advantage be reinforced with old steel rails, bars, or similar material. The top of the concrete raft should be brought up to within 3 ft. of the ground surface.

Building Centre Walls

The position of the two centre walls which support the boiler can then be marked out and built up 9 in. thick of common bricks with a 4½ in. lining of firebricks bonded in on the gas side of the walls. Lime mortar should not be used, only fireclay being employed. The specially shaped seating blocks which are in contact with the boiler need not be fixed in position until the boiler is ready to be lowered on to them. It will be seen from the plan view, Fig. 7, that the centre walls do not extend the whole length of the boiler, being stopped short at the front end to provide a passageway to the side flues.

Building Outer Walls

The two outer walls of the settings, 9 in. thick of common brick, may now be built up from the foundations, and it will be convenient to leave these uncompleted at about 3 ft. high until the boiler is in position on its centre wall.

Filling Base of Settings between Walls

The space between the centre and outer walls at the base of the settings can then be filled in with well-rammed earth or broken bricks and

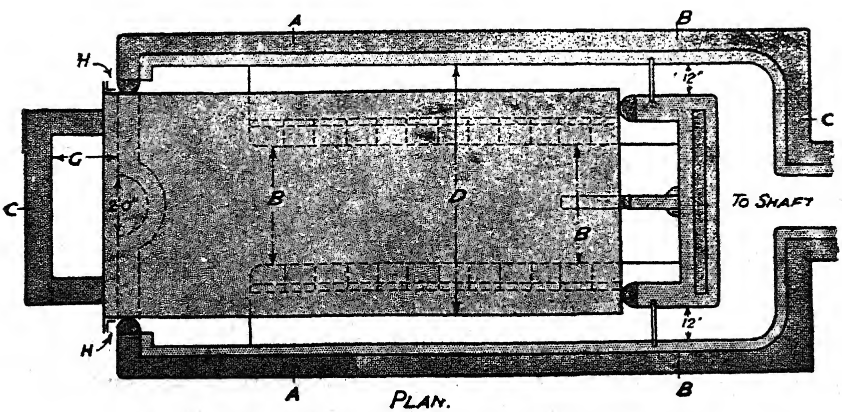


Fig. 7.—Plan view of Lancashire-type boiler settings

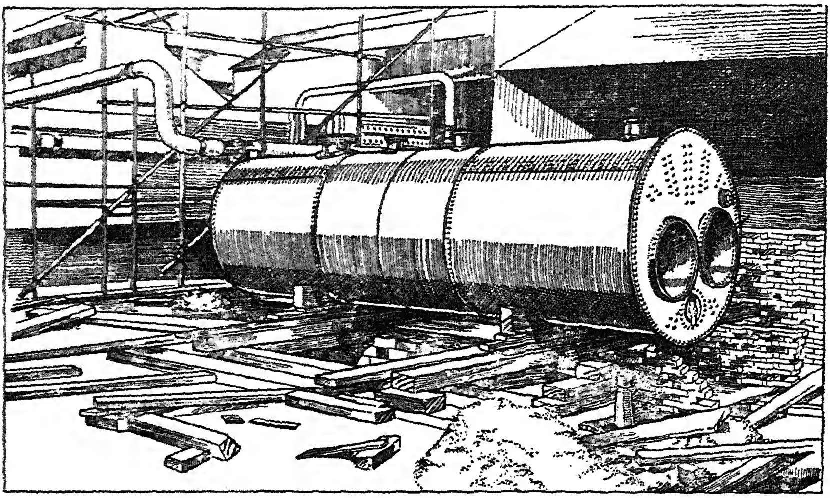


Fig. 8.—THE FIRST OF TWO BOILERS BEING MOVED ON TO ITS SETTINGS TO THE RIGHT OF THE PICTURE

The boiler is being moved sideways without rolling, by means of traversing jacks.

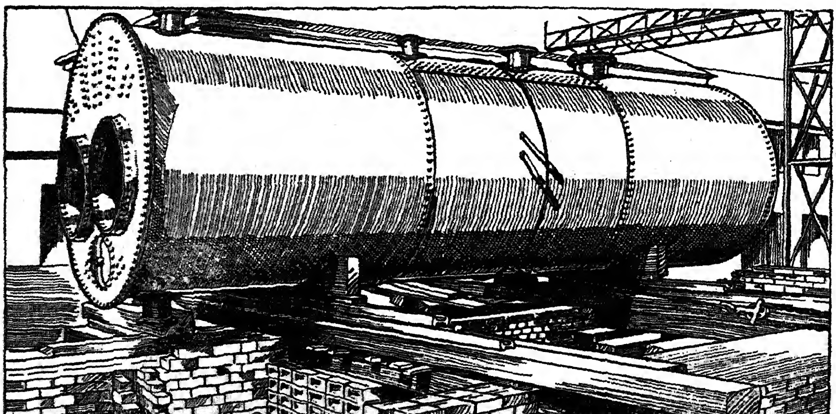


Fig. 9.—THE SAME BOILER AS SEEN IN FIG. 8, FROM THE OTHER SIDE

Showing the timbers packed up with bricks to carry the boiler over the foundations.

rubble set with cement. The only function of this portion is to carry the short cross walls which hold the seating blocks laterally and form the bottom of the side flues.

PLACING THE BOILER ON ITS SEAT

Suitable Timber Track to Settings

By making a suitable timber track along the bottom of the main flue, of sufficient height to keep the boiler well clear of the brickwork, the boiler can be brought by the methods already described over the position in which it will be finally fixed (see Figs. 3, 4, and 5).

Centring and Levelling Boiler

The boiler must lie centrally along the settings and be level in the direction at right angles to its length. This can be checked by placing a spirit level across the boiler on one of the standpipes. At this point we are not concerned with the level of the boiler in the direction of its length.

Lowering Boiler on Seating Blocks

With a lifting jack under the vertical centre line at each end of the boiler take the weight and remove some of the timbers. The seating blocks may now be placed loosely in position on the top of the centre walls of the main flue. The two seating blocks, one on each side at the extreme back end of the boiler, should now be brought up so that their inside faces are flush with the inside faces respectively of the supporting walls, and the jack at that end lowered until the boiler just touches the top of the two blocks without putting weight on them.

Getting Proper Fall in Length

The front jack is now lowered until the boiler is level along its length, and is then lowered a further 1½ in. or 2 in. to give the necessary fall. The boiler is now in its final position, but not yet supported by the brickwork along the length of each side of the boiler ; push the seating blocks towards the centre until they touch the shell plates and fix them finally with fireclay backed up by the two flooring walls previously mentioned. When the fireclay has set, the jacks and timbers can be taken away.

It will be noticed that, due to the fall in the boiler, the seating blocks will be slightly wider apart at the front end than at the back, but this is no detriment, and it is more satisfactory to get the fall in this manner than by building the whole settings and concrete foundations on the incline.

COMPLETION OF THE SETTINGS

The Arch Slabs

The outer side walls with their firebrick linings bonded in can now be carried up to the required height to carry the arch bricks or slabs which roof in the side flues. These slabs are of special shape and construction and rest against the shell plate at one end and are supported by the side walls at the other end, as shown in Figs. 6 and 10.

To allow for the expansion of the boiler from cold to working temperatures, these arch slabs are allowed to " breathe " slightly by leaving an air space behind them, as indicated in Fig. 6.

Building Front Wall

The wall closing in the front ends of the external flue can now be built up, and the portions of the wall immediately in contact with the boiler should preferably be made of bull-nosed bricks, so as to leave as much of the shell plate as possible to contact with the hot gases.

It will be seen from the plan of the settings that the portion of this wall under the boiler is set back, to clear the blow-off elbow, and it is advisable to have the blow-off elbow fixed in position before this portion of the wall is built, so as to give more room for using a long spanner to tighten up the nuts. If the blow-off elbow is left off until the wall is complete, it is very difficult to get at the nuts at the back and adds unnecessarily to the work.

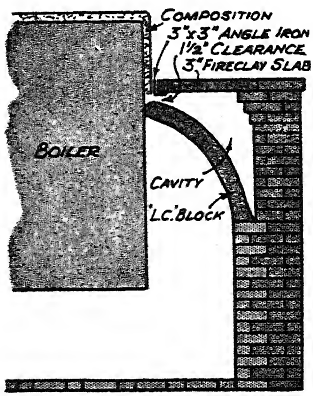


Fig. 10.—METHOD OF PLACING THE FIREBRICK ARCHES IN POSITION

They rest lightly against the back end of the boiler and can accommodate themselves to any movement, due to expansion, of the boiler.

Providing Cleaning-out Door in Front Wall

As low down as possible in this front wall is usually fixed at least one cast-iron cleaning-out door, giving access to the external flues. Some makers provide two access doors in the front wall, which makes for greater convenience, although the second door is not absolutely essential.

Keep Circumferential Seam Exposed

It is recommended that this front wall always be kept clear of the circumferential seam carrying the front end-plate of the boiler, and if, as is general, the boiler is to be insured, the insurance company will take particular note of this point.

It is good practice to build the front wall not less than 2 in. clear of the angle ring to which the front end-plate is riveted.

A firebrick lining, bonded in as much as possible, should be included on the gas side of the front wall.

Brickwork at Back of Boiler

Attention can now be given to the brickwork at the back end of the boiler, and the plan in Fig. 7 shows the most usual arrangement adopted. The frame carrying the damper in each side flue should be fixed in position first and the brickwork then completed round it.

The three short walls touching the back end, and parallel with the axis of the boiler, form the downtake making the passage for the hot gases from the internal furnace tubes to the bottom flue under the boiler. The centre of these three walls is called the mid-feather wall, and assists in supporting the curved firebrick arches usually employed in the downtake.

Firebrick Arches at Back

The section, Fig. 10, shows these firebrick arches and the method of placing them in position. They rest lightly against the back end of the boiler and can accommodate themselves to any movement due to expansion of the boiler.

Firebrick linings are provided in the downtake walls, and the mid-feather wall is generally constructed entirely of firebricks.

The whole of this portion of the boiler settings is roofed in with firebrick slabs, supported where necessary with angle-iron girders to carry the weight. The distance from the back end of the boiler to the inside face of the downtake wall varies somewhat with the size of boiler, being about 2 ft. for the smaller sizes, up to 2 ft. 6 in. in the larger sizes.

The two external side flues are now brought together beyond the downtake into one main flue leading as direct as possible to the base of the chimney-stack. This flue is lined with firebricks and arched over with firebricks, covered with slabs or specially designed firebrick arches. All changes in direction should be as gradual as the site available will allow, and the chimney should be as near the boiler as possible.

PREVENTING AIR LEAKAGE

It is very essential that the joints between the back end of the boiler and the downtake walls should be gas-tight, so as to prevent the gases from the furnace tubes passing directly into the side flues without giving up their heat to the boiler.

Methods to Ensure Tight Joints

Various special methods can be adopted to ensure a tight joint and at the same time allow for expansion of the boiler. One such method, typical of the principles involved, consists of fixing two vertical lengths

of angle iron to the back end of the boiler central with each outer wall of the downtake and of the same height. A gap left between the projecting flange of the angle iron and the downtake wall is made up with plastic or asbestos fireclay. As the boiler expands lengthways on warming up, the flange bites deeper into the fireclay and in the subsequent contraction and expansion moves in the groove thus formed.

A similar horizontal angle iron on the back end of the boiler level with the roofing slabs completes the system.

Pit at Firing End

A small pit roofed with stone flags or chequer plating is provided at the firing end of the boiler to give convenient access to the blow-down elbow and cock. Blow-down piping from the cock is generally led into a sump, in order to allow the hot water from the boiler to cool down before being passed into the works drains. If the blow-down piping is trenched to the sump, an air-tight joint should be made where the piping enters the sump to prevent water vapour rising into the trench and rusting the pipe and blow-down cock.

Fixing Boiler Fittings and Pumps

With the construction of the firebrick bridge in each furnace flue the boiler setting is then complete, and the water gauges, stop valves, and other fittings, together with the firebars and furnace doors, can be fixed in their respective positions.

The feed pump or pumps and the steam piping from the main stop valve can be connected up. The manhole lid on the top of the boiler should, however, be left off until the boiler is filled with water.

FILLING THE BOILER

Drying Out Boiler

The filling of the boiler may be rather a long job, especially if it has to be done by hand, but when it is completed in due course, the manhole cover can be finally fixed and a fire, preferably wood, can be lighted in the furnaces. Undue eagerness to get steam pressure showing on the gauge should definitely be avoided, and only very small fires should be made. The object of warming up is primarily to dry out the setting and not to raise steam, and a fortnight spent in gradually drying out is not excessive, if such a period is available. In any case the warming up should be done as slowly as possible (several days) to avoid any rapid expansions or distortions. The dampers in the external side flues should be opened only as much as is necessary to keep the fire alight.

During the period of drying out the lagging material can be spread on the exposed portion of the boiler shell and steam piping, as the commoner forms of lagging have to be put on as a wet paste.

Chapter IV

STEAM-ENGINE ALIGNMENT

THE importance of extreme care when erecting an installation has been stressed elsewhere in this book. Here is an example of the troubles which will arise if such care is not taken. Indeed, the method outlined is applicable in principle to all other prime movers, and, in general, were better adopted first instead of last.

A large reciprocating steam-engine went well for a number of years, when the following unusual symptoms evinced themselves :

(1) The engine appeared to be moving heavily after the steam had been cut off and before coming to rest. Thus the inertia in the flywheel was of less value.

(2) Heavy grunting took place in the cylinder at the rear end on slowing down.

(3) Steam was found escaping from the front cover joint at the bottom.

(4) Engine was less " lively " generally.

The symptoms enumerated above took some little time to develop, as a large steam-engine will maintain efficiency much longer than other types of prime movers which require frequent periodical adjustments.

Attempts to Remedy the Trouble

The first attempt at remedy was to endeavour to tighten up the nuts on the front cover.

The grunting indicated pressure on the lower wall of the cylinder, which should not have happened, as this load should have been taken to a great extent by the tail-rod slide. This part of the engine had not, however, given any symptoms of distress, and it was also found that an attempt to tighten up the front cover was not satisfactory.

All these points being noted in the engine log book, it was now considered necessary to have a complete investigation, as mal-alignment was suspected.

The first steps taken were to obtain as much information as possible with the engine in its running condition and before stripping it. The operations here were somewhat limited, as the only positions in which particulars could be taken were the main and tail-rod slides.

A level was placed first in the main slide and showed a marked drop at the cylinder end of the slide. The level was then placed on the tail-rod slide and this was found to be somewhat less affected. It was dis-

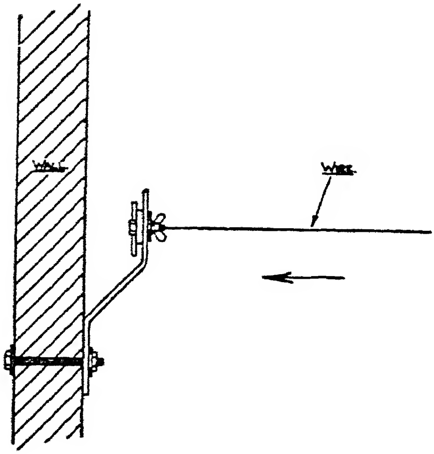


Fig. 1.—SIDE ELEVATION AND FIXING OF WALL-ATTACHMENT, SHOWING LATERAL ADJUSTMENT

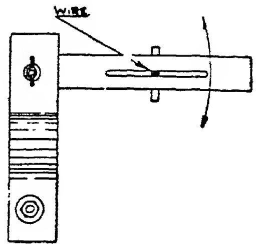


Fig. 2.—FRONT VIEW OF ATTACHMENT, SHOWING ADJUSTMENT VERTIC ALLY THROUGH ARC

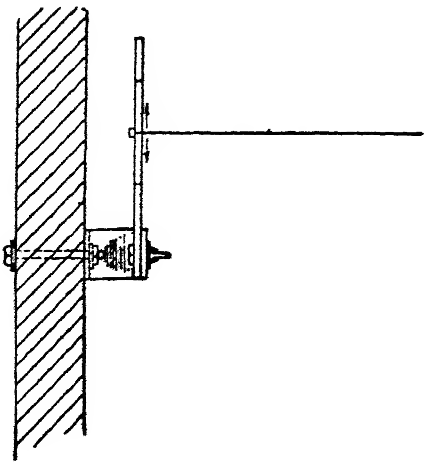


Fig. 3.—PLAN OF WALL ATTACHMENT, SHOWING LATERAL ADJUSTMENT

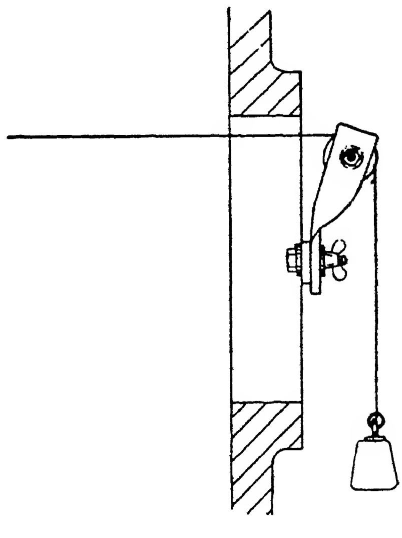


Fig. 4.—FRONT SECTION OF BEDPLATE IN ELEVATION, SHOWING WIRE TENSIONING ATTACHMENT

covered here that the crosshead slipper was not actually touching the slide and therefore failing to achieve its object. On placing the level on the tail rod itself, it was noticed that it was pointing upwards at the rear end.

All these points were recorded and preparations made for stripping the engine of all parts which would impede the operation of lining through.

Stripping the Engine for Checking Alignment

The procedure was carried out in the following manner :

(1) To remove tail-rod crosshead.

(2) To remove tail-rod slide.

(3) To remove packings and glands from back cover.

(4) To remove back cover.

(5) To remove packings and glands from front end of cylinder.

(6) To remove cotter which secures piston rod to crosshead.

(7) To remove piston and rod complete.

(8) To disconnect connecting rod at large and small end, and remove rod from engine.

The method used for lining through on this particular engine was by the use of a light-gauge piano wire.

Having removed all obstructions detailed above, the only part left was the main crosshead in the slide. This was purposely retained as it was to be checked at each end of its stroke.

A sufficient number of parts had now been removed to obtain a clear path through the main portions of the engine, including the boss of the crosshead from which the piston rod had been removed.

Fixing the Aligning Wire

The first step in the actual lining-through operation was to fix the positions for locating the wire. It was essential that these positions should be beyond any point at which the measurements were to be taken. To fulfil these conditions the engine-house wall was used to carry the attachment at the rear end, while the front of the bedplate was used at the opposite end of the engine. The fittings used for the wire attachment were quite simple, although

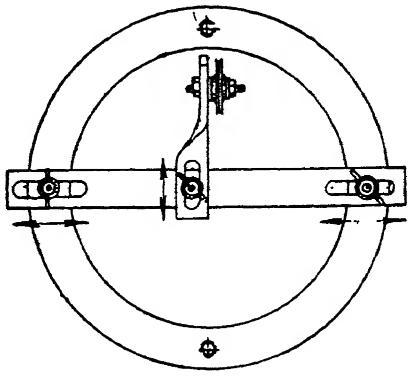


Fig. 5.—Front view of tensioning attachment, showing both lateral and vertical adjustment

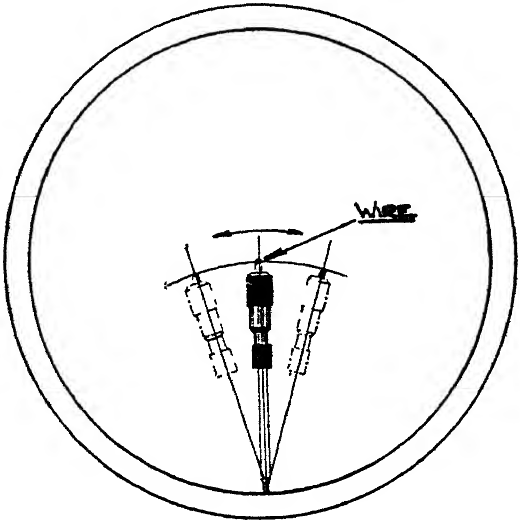
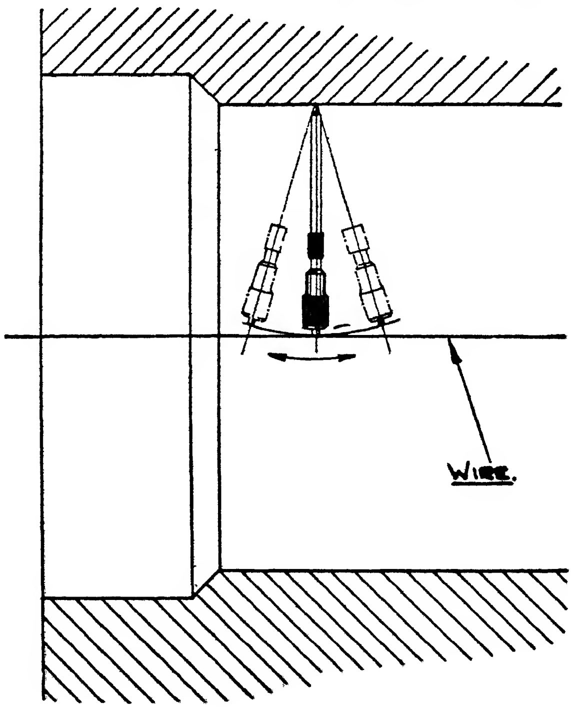


Fig. 6.—TAKING SWING ACROSS WIRE TO OBTAIN MINIMUM DISTANCE

provision was necessary for fine adjustment in setting up. Figs. 1, 2, and 3 show the method of securing the rear end at the engine-house wall, and Figs. 4 and 5 show the method of attachment at the front end of the bedplate. It will be noticed in this case that the wire is run over a pulley and has a loading weight fixed to its extremity. This was used to strain the wire sufficiently to eliminate any appreciable sag which would otherwise have seriously affected the micrometer readings. In setting up, the wire was attached to the fixed end and passed along through the cylinder and stuffing-box, through the boss of the main crosshead and over the pulley to the weight.

Fig. 7 (*below*).—TAKING SWING LENGTHWISE WITH WIRE



Final Adjustment of the Wire

Final adjustment was then made at the two points chosen, as the datum from which

all other measurements were taken. This operation required extreme care, and the provision of suitable adjustments, such as the slotted brackets for supporting the ends of the wire, will be fully realised. The two points chosen as the datum were the rear end of the cylinder bore, after making certain allowance for wear in the cylinder, the other one being in line with the crank and passing across the centre of the crank pin. This position was obtained by measurement and verification from the drawing of the engine, as this particular point is not a centre in the same manner as the one at the cylinder end. The remaining points at which measurements were taken are—(*a*) main crosshead pin bore, i.e. between faces for small end; (*b*) main crosshead in piston-rod bore (front end of slide); (*c*) main crosshead in piston-rod bore (rear end of slide); (*d*) housing for gland packing (front end of cylinder); (*e*) front of cylinder at end of stroke; (*f*) rear end of cylinder (check datum).

Taking Measurements for Checking Alignment

Having finally fixed the wire in position, the next step was the taking of the measurements from the various positions. In describing this operation it should perhaps first be mentioned that the tool used in measuring was the internal micrometer. The choice of this instrument was decided upon, owing to the fact that it fulfils the requirements of sensitivity and accuracy, while its portability and range make it ideal

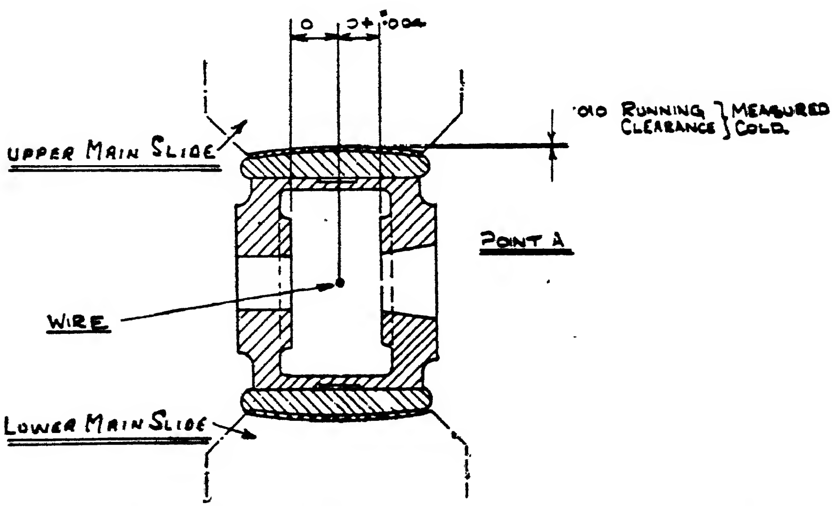


Fig. 8.—MEASUREMENTS AT POINT *A* TAKEN BETWEEN FACES INSIDE CROSSHEAD
Showing ·002 in. out of centre, the right-hand side being widest.

for use on any outside job, such as the one being described. Some skill, however, is necessary, as it is a matter of "touch" and careful swinging over the minimum distance between the location point and the wire. The necessary length of micrometer staff was selected to suit the position in the engine, and the fixed end held and pivoted on the wall of the cylinder or whichever part was being measured. Trial swings were made by allowing the micrometer head to clear the wire when swung from left to right and front to rear. The head was then slightly opened up until the wire could be felt to "twang" on just touching. Figs. 6 and 7 show the method of swinging the micrometer. The most sensitive reading was taken from all four points under these conditions and were the ones which were recorded. In the examples given the smallest of the two readings in each case, i.e. vertical or horizontal, is indicated by the zero reading "0" and the largest by the difference between the two. Thus the amount out of centre or position relative to the wire is only half this amount. This is obvious because of the fact that: Could the wire be moved towards the farthest wall by half the amount, the original zero "0" reading would become "0" plus half the difference, and the other reading "difference minus half difference," or equal in each case.

The reason for moving the main crosshead and taking readings at each end of the slide is that this procedure gives the actual amount out of parallel over the working stroke and in a similar manner to the readings taken in the cylinder.

The whole of the readings were taken and tabulated as indicated in Figs. 8, 9, 11, 12, 13, and 14.

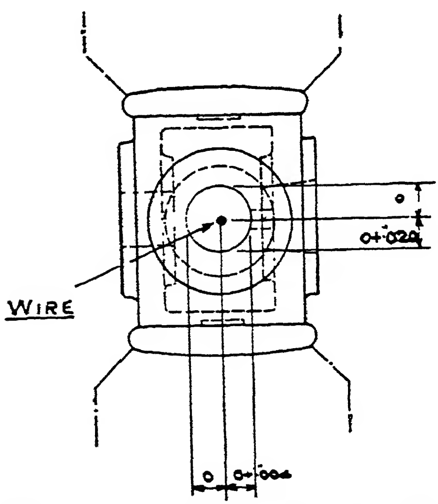


Fig. 9.—POINT *B*—TAKEN IN PISTON-ROD BOSS OF CROSSHEAD AT FRONT END OF GUIDE

Vertical Check—Actual centre of bore, ·010 in. low to wire = half ·020 in.

Horizontal Check.—Actual centre of bore, ·002 in. to RH of wire = half ·004 in.

Analysing the Horizontal Measurements

In summing up the general alignment the lateral or horizontal readings were first considered and as they were of such low value it was decided to ignore them. This decision was rightly taken, as in this case a very large engine was being dealt with and such small errors would be comfortably absorbed in the general run-

ning clearances. A point of interest is, however, the fact that the main crosshead was slightly away to the right-hand side of the wire. Taken practically, this error could have been improved by moving the wire away from the crankshaft at the front end of the engine when the wire was originally set up, but as a fair test must always be made in the most exacting manner this observation had to be reserved till after the examination.

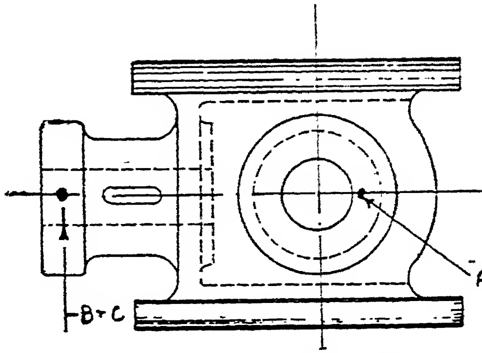


Fig. 10.—Elevation of crosshead

Showing where measurements at points *A*, *B*, and *C* are taken. Actual positions "inside" the crosshead. See Figs. 6, 7, and 9.

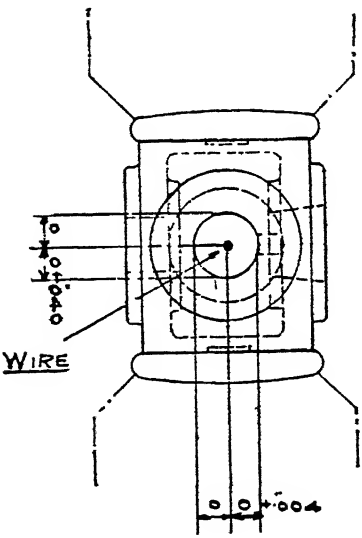


Fig. 11.—Point *C*—taken in piston-rod boss as above but with crosshead at rear end of slide

Vertical Check.—Actual centre of bore ·020 in. low to wire = half ·040 in.

Horizontal Check.—Actual centre of bore ·002 in. to RH of wire = half ·004 in.

Analysing the Vertical Readings

We can now consider the figures given in the series of vertical readings. These were of a serious nature and had to be very carefully analysed. It will be noted that the lowest point of the engine relative to the lining-through wire was almost immediately below the front end of the cylinder and from which point the main crosshead slide slopes upward in the direction of the crankshaft whilst the cylinder slopes in the reverse direction towards the tail-rod slide. This immediately indicated the seat of the trouble, as far as could be surmised up to the present, and was supported by the fact that blowing of the cover joint took place here. The grunting of the piston when travelling towards the rear end was explained by the fact that it was travelling up-hill, and the failure of the tail slide in supporting it being due to the general tendency of the piston rod to be pointing upwards and keeping the tail-rod crosshead clear of its slide.

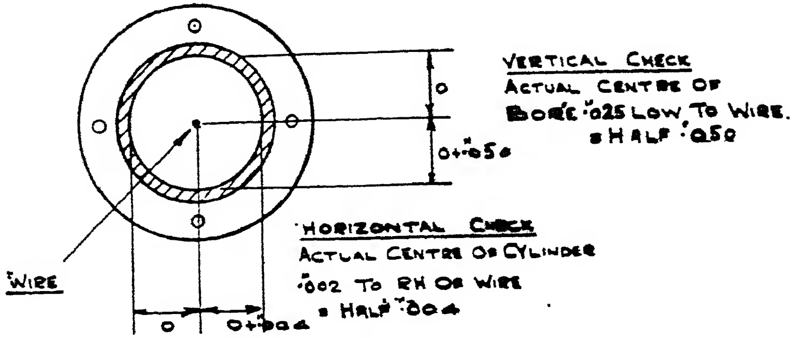


Fig. 12.—POINT *D* TAKEN IN STUFFING-BOX HOUSING

Examining Foundation Block for Subsidence

Having dealt with the mal-alignment of the engine, it was decided to carry these examinations down to the concrete foundation block. To do this the pit covers were removed so that the block could be inspected at the seat of the trouble. It was here that a crack was found extending from a point below the front of the cylinder down to the base, and although this had not the effect of actually severing the block it constituted a fault of some magnitude. Fig. 15 indicates the various faults in exaggeration.

Remedying the Faults

The examination was by now complete and, as certain deductions had been made from time to time, it was now possible to piece these together and decide on a remedy. As the whole of the trouble had been localised

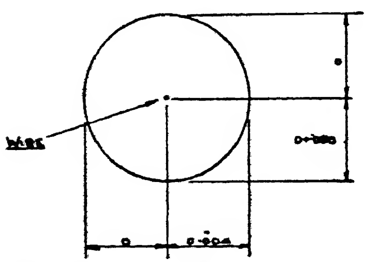


Fig. 13.—POINT *E* TAKEN AT FRONT END OF CYLINDER

Vertical Check.—Actual centre of cylinder, ·030 in. low = half ·060 in.

Horizontal Check.—Actual centre of cylinder, ·002 in. to RH of wire = half ·004 in.

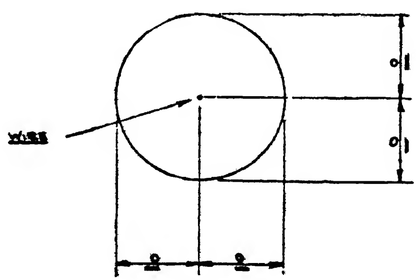


Fig. 14.—REAR SETTING POINT (DATUM)

Point *F* taken at rear end of cylinder. Vertical and horizontal checks, correct as set.

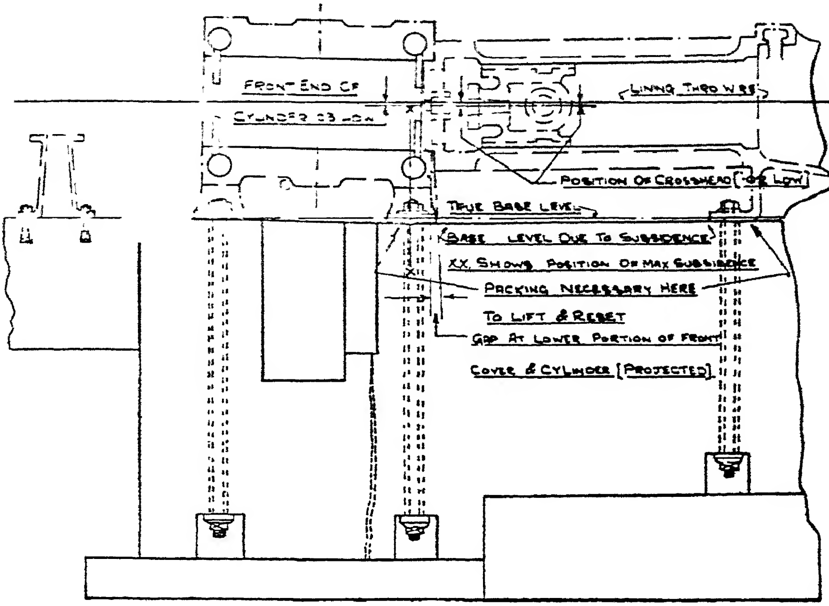


Fig. 15.—SHOWING EXAGGERATED CONDITION OF MAL-ALIGNMENT

at one point, it was obvious that the most satisfactory remedy would be to commence here and return the engine to its original true setting. This was to lift up and reset the parts which had dropped. The first step was to slack off the foundation bolt nuts, at each end of the cylinder, and also the bedplate, this latter being necessary owing to its being bolted to the main guide, and forming a solid unit with the cylinder. It will be remembered that no actual measurements were taken in the bedplate itself, except the lateral one, as the only connection between the crosshead and the crank is through the rotative and angular movement of the connecting rod. The more important point was to relieve the securing studs at each end of the guide of such an undue strain as had caused the blowing at the front cover.

The next step was to lift up the affected part. This was done by the use of jacks in conjunction with wedges. Some care was necessary in this operation, as it was essential that the lifting should not be beyond just the amount necessary for insertion of the new packings. The driving in of the wedges had also to be carried out simultaneously at each side of the foot of the cylinder and bedplate respectively. It had previously been decided what thickness of packings was required, and these had been prepared and were inserted. The bedplate and cylinder were then

lowered and the underside of each filled in with new grout where necessary.

Re-aligning the Engine

The engine was now ready for re-aligning, using the same two points as a datum. It was necessary to "correct" the one at the cylinder end slightly as this had been affected by the lifting up of the front end. A further series of measurements along the whole was found to prove very satisfactory.

Dealing with Crack in Foundation Block

While all this was being done the foundation block was receiving attention. The services of a contractor who specialised in this work were called upon, and the sides of the crack were plugged up, while holes were drilled into its centre and down to the base for forcing in liquid concrete. By this means the disturbance in the ground at the points below the base was attacked and reinforced. After all concrete had set, the engine was finally bolted down and one or two final checkings made before removing the wire. All was again found to be correct and the engine assembled.

The only remaining point which now required adjustment was the tail-rod crosshead slides, and this was done to allow it to take its proper share of the load.

A trial run was made, at the end of which the most outstanding feature was its perfect freedom of movement before coming to rest. It was again put into commission and has since done years of satisfactory service.

MAL-ALIGNMENT DUE TO FAULTY INSTALLATION

We will now consider mal-alignment due to carelessness or inefficiency in laying down plant. As has been mentioned, the manufacturer is usually called upon to supply the skilled labour necessary for carrying out this work. Under these circumstances the likelihood of trouble would be practically negligible, as the outside man is always chosen for his special knowledge and reliability. A case of mal-alignment will be considered here where the circumstances are the exception rather than the rule. A steam-driven air compressor had been in use for some years, giving every satisfaction until the time arrived when it was found to be too small in its output to supply the increasing demands of the concern. It was therefore taken out and purchased by another company, whose compressed-air requirements were somewhat less and well within the capabilities of the engine. The installation work was on this occasion carried out without calling upon the assistance of the manufacturer.

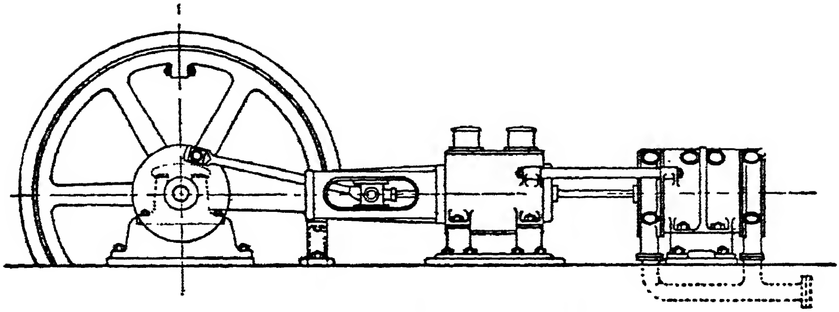


Fig. 16.—Elevation of steam-driven air compressor

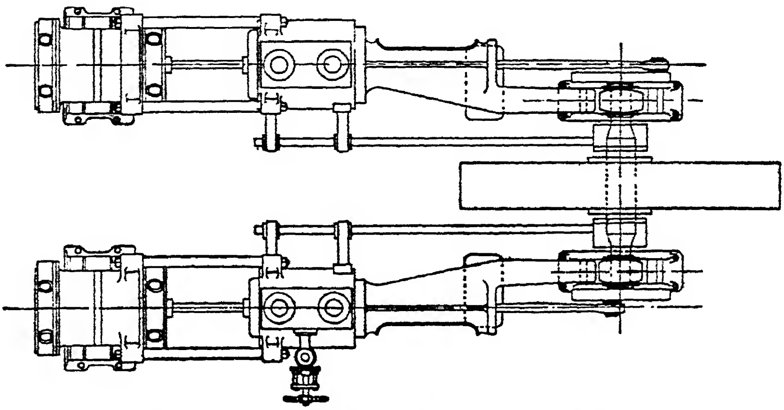


Fig. 17.—Plan of steam-driven air compressor

It was put into commission, and its performance did not appear to be very satisfactory.

An Actual Example

A description of the type of engine must here be given, so that the reader will be enabled to follow the course of events.

The engine was of the compound fixed type with heavy cast-iron bedplates, one at each end of the crankshaft, and one air cylinder being arranged tandem fashion behind each steam cylinder. It will thus be seen that while each side of the engine, with one steam and one air cylinder, forms a complete unit, they are only connected by the crankshaft, to which they are attached respectively at each end. Figs. 16 and 17 show the layout of the engine in elevation and plan.

Such an arrangement obviously calls for careful setting up of each

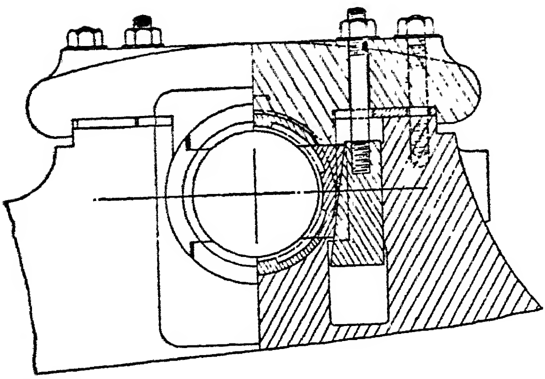


Fig. 18.—Four-part bearing in half section, showing adjusting wedge

side in relation to the crankshaft. The chief disturbing feature was an excessive heating of the main bearings. The first reaction of the engineer was to slacken these off. This was a simple operation, as they were of the four-section type, i.e. with top, bottom, front, and rear sections (Figs. 18 and 19). The former, i.e. top and bottom, were controlled by the thickness of the shims under the caps, while the front and rear sections were adjustable by wedges which in the slacking off were, of course, lowered. The result of this adjustment was to reduce the heat generated, but at the expense of a very heavy knocking, owing to the excessive clearance between the front and rear sections and the shaft. The most satisfactory compromise which would allow the engine to work on load resulted in a backwards and forwards movement of $\frac{3}{32}$ in. at the crank and each side of the engine. Some allowance had been made for the fact that the engine was not new, and this unsatisfactory state of affairs was continued in the hope of gradually reducing the movement by tightening up the wedges, thereby allowing the bearings to readjust themselves to the new conditions. It should be borne in mind here that the movement of $\frac{3}{32}$ in. taken by the crankshaft

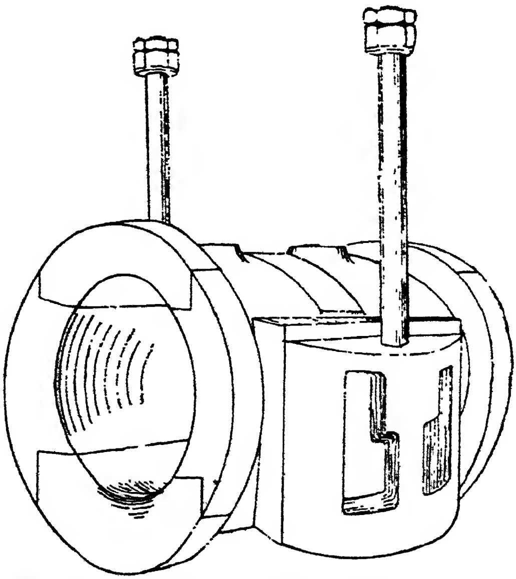


Fig. 19.—Perspective view of bearings and wedges

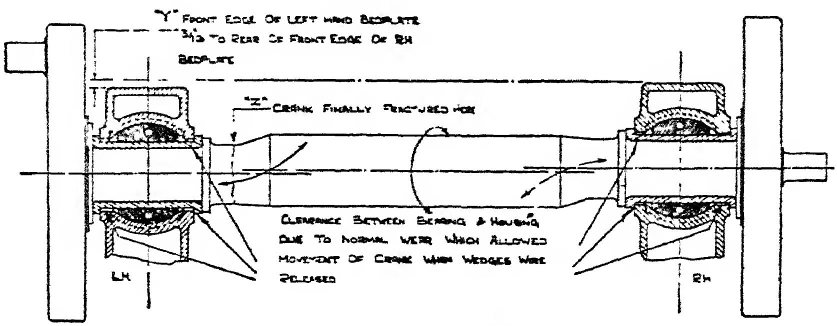


Fig. 20.—PLAN SHOWING EXAGGERATED EFFECT OF TIGHTENING UP BY WEDGES AND CONSEQUENT DISTORTION OF SHAFT AT EACH END DUE TO MAL-ALIGNMENT

during the period of heavy knocking was only possible because the bearings had been in use for some years, and were therefore in a worn condition. Had new bearings been fitted they would not have allowed this amount of movement to take place, because their outside restings would have been butting up to the bore of the housing in the bedplate. The surfaces on the inside would have been fitting to the shaft, allowing only just the necessary amount of running clearance. It is therefore only after a period of running, during which wear does actually take place, that the wedges are drawn up to push the front and rear sections forward and support them in a position which compensates for the amount of wear.

A study of Fig. 18 will show the type of bearing and its adjustment. The effect of gradually re-tightening up the bearings was to throw a tremendous strain on to the shaft in the following manner :

Bending stresses were being set up at the points close to the inner faces of the bearings, and these were being constantly reversed and merged with the torsional strains due to the shaft being revolved. Fig. 20 indicates the nature of the bending stresses.

The Result—a Broken Crankshaft

It was therefore not long before disaster occurred in the breaking of the crankshaft at the point mentioned near the left-hand bedplate. Some outside assistance was now imperative, and the manufacturer was called in to investigate the matter and, of course, supply a new crankshaft. In considering the facts of the case, it was clearly apparent that the trouble was mainly at the front end of the engine, and it was decided to commence investigation here. A new shaft was prepared and despatched to the job, and a new set of bearings for each side of the engine were also put in hand by the manufacturer.

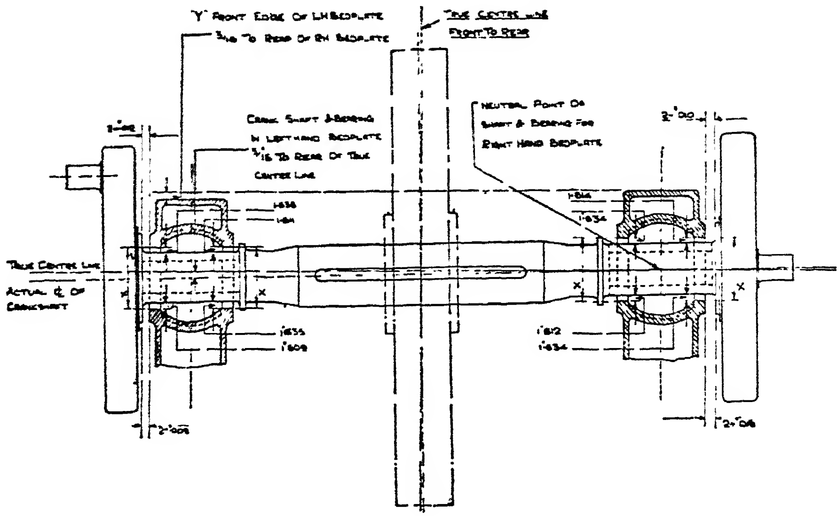


Fig. 21.—Plan showing crankshaft set up for taking measurements

Tracing the Source of Mal-alignment

In taking the first step it was decided to reproduce the conditions existing before the breakdown, and to do this the bottom sections of the bearings were left in position in the bedplate and all other parts, such as broken crank, connecting rods, etc., removed. The new shaft was lowered into position on the bearing sections so that measurenents could be taken from the shaft to each housing to determine whether alignment or mal-alignment existed here. Firstly a series of four measurements were taken across the machined housings in each bedplate as indicated at *X* (Fig. 21). These were to prove whether the recent knocking had produced any appreciable wear on these surfaces, which were next to be used as checking points in conjunction with the shaft. Fortunately they were still unaffected, and the next set of measurements were taken. These were four in number in each bedplate, i.e. two at the front and two at the rear. These positions, with the actual measurements, are shown in Fig. 21.

Considering these, it will be seen that in all cases, taking the two measurements at one side of the shaft to the housing at front and rear, there is a difference varying from 1·611" to 1·638" (front L.H. bedplate) to 1·614" to 1·634" (front R.H. bedplate), with somewhat similar differences of 1·609" to 1·635" (rear L.H. bedplate) to1·612" to 1·634" (rear R.H. bedplate).

Possible Causes

As these two measurements in either housing should be equal or approximately so, it is obvious that the shaft is lying at an angle to the true centre line of the engine, from front to rear. This is due to one or both of the following causes:

(*a*) One bedplate being out of parallel with the other.

(*b*) One bedplate being in advance or behind the other, relative to the true crankshaft centre line.

It was therefore decided to provide a check on the above measurements by taking a further set between the machined faces of the crankshaft discs, to the machined face of the bedplate housing, which space would be normally occupied by the bearing flanges.

The results of these readings, taken at each bedplate, are:

2 in. plus	·012	front bedplate L.H.	Fig. 21.
2 in. minus	·010	front bedplate R.H.	
2 in. minus	·009	rear bedplate L.H.	
2 in. plus	·015	rear bedplate R.H.	

The differences between the front and rear readings are ·021 in. at the left-hand bedplate and ·025 in. at the right-hand bedplate.

Thus the amounts these are out of parallel confirm the earlier figures and tend to prove that the trouble is due to (*a*) or (*b*).

Checking Alignment

To prove (*a*), measurements were taken at points across the front of the two bedplates, and similar suitable positions across the cylinders at the rear. These agreed sufficiently close to show that the bedplates were parallel. This now left conclusion (*b*) as the obvious one, i.e. that the left-hand bedplate was fixed to the rear of the right-hand one. To get at the actual figure it was only necessary to find the average error per foot of crankshaft length and multiply this by the distance between the centre points of the bearings. This amount was approximately $\frac{3}{16}$ in. and is indicated by the letter *Y* in Figs. 20 and 21. The decision to take the right-hand bedplate as the one carrying the neutral centre was because the shaft had actually broken at point *Z*, and the greater amount of heating up and knocking had taken place here. The actual effect of attempting to re-tighten up the bearings can now be clearly visualised. As each bearing was made to tighten up on the crankshaft they were tending to bend it locally at each end, whereas by allowing full play, i.e. $\frac{3}{32}$ in. forwards and backwards each side, the whole mal-alignment of $\frac{3}{16}$ in. (approximately) was being neutralised.

Re-aligning the Engine

The remedy or correction to prevent a recurrence of the trouble with the new shaft had now to be made. The only satisfactory course was

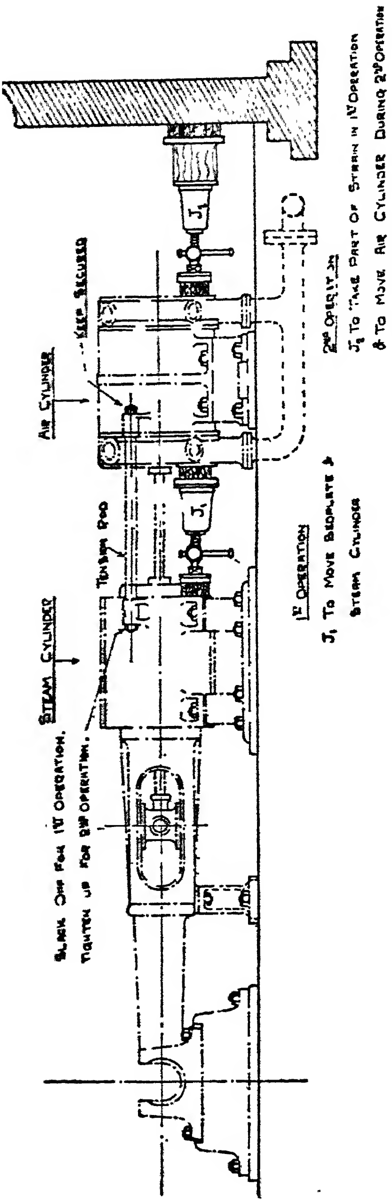


Fig. 22.—Layout of engine (stripped condition), showing jacket arrangement

to bring the engine into alignment by moving forward the whole left-hand side unit, comprising bedplate, guide, and steam and air cylinders. This was rather a tall order, although assistance was gained by the original mounting of the engine parts on separate sole-plates. Thus it was possible to slide the cylinder and bedplate feet along these sole-plates which were being retained on the foundation.

The procedure was as follows:

It was decided that while it might not be possible to move such a heavy mass owing to the thrusting strain on the rear-engine house wall it would be made much simpler by moving the bedplate and steam cylinder first and following up with the air cylinder afterwards. By this method the load moved would be very considerably less while the holding-down bolts in the air cylinder would assist in taking the strain from the engine-house wall. Jacks were mounted in position and timber structures were made to distribute the load, the one at the engine-house wall being of some considerable proportions. Fig. 22 shows the layout with the two jacks J.1 and J.2 in position for moving the bedplate and steam cylinder. It will be observed that in the particular operation the jack J.2 at the rear end is only tightened up sufficiently to distribute the load between the air-cylinder bolts and the wall as mentioned. All nuts were slacked off from the bedplate, guide, steam-cylinder

feet, and the tension bars between the steam and air cylinders. The jack J.1 was then screwed out until the fore part of the engine had been moved the requisite amount. It should be mentioned that there was sufficient clearance in all the holding-down bolt holes, excepting the one or two from which the bolts were withdrawn and later replaced by bolts with smaller shanks. Having completed this, all holding-down nuts were tightened up (excepting, of course, the ones on the tension bars) and the jack J.1, with its steel and wood packings, removed.

The next step was to move forward the air cylinder. The holding-down nuts were now slacked off on this cylinder, and as the jacking arrangements had been previously set up it was only necessary to screw out the jack J.2 to push the cylinder forward. This operation was actually assisted by the tightening up of the nuts on the tension bars, and thus the cylinder was drawn from the forward end at the same time as it was pushed by the jack at the rear.

The amount of movement was controlled by the shoulders on the tension bars which formed a definite stop between the two cylinders. The holding-down nuts on the air cylinder were now tightened up and the jack, with its packings, removed.

Re-checking

The engine was now ready for re-checking, and this time figures were obtained which proved that satisfaction had been gained. The new bearings were available by this time and were fitted into their housings. The new crankshaft and flywheel were fitted and connecting rods coupled up. All that was necessary now was to check up the piston end clearances as some considerable alteration had been made and which necessitated this operation. Having made some slight adjustments, the engine was again started up, and after a normal period of running-in proceeded to carry on with a more satisfactory performance in its new lease of life.

Chapter V

INSTALLATION OF ELECTRIC MOTORS

(Direct Coupled, Gear, and Belt Driven)

IN the case of small machines up to, say, 50 h.p. it is permissible to bolt the motor to strong timbers, which in turn will be secured to and supported from the floor or walls of the building in which the motor is installed, and it is, of course, quite in order to grout the motor-foundation bolts into a concrete floor provided this is sound and of sufficient depth.

When the method of securing the machine to the building structure is adopted, however, one must be sure that the drive is good, i.e. that there is no vibration and that the belt is not too tight, but, as it is impossible in industrial practice to be sure that good conditions can be maintained indefinitely, it will pay to put in a concrete foundation when the contemplated installation is to be permanent, or even semi-permanent.

If the building construction is such that structural steelwork members are available, the motor may be bolted to these if they are of sufficient strength, and this method is adopted in many factories. In any case, the sole object to aim at in planning the foundations is to ensure that the motor is firmly supported and secured so that it cannot move or vibrate when running.

Concrete Foundations

A well-made concrete foundation will last indefinitely and will ensure correct alignment and good drive conditions throughout the life of the machine, so that it will be well worth while to spend some time on this part of the installation. The first detail to be settled is the size, and this factor depends on the nature and carrying capacity of the subsoil.

For average cases, where the foundation can be carried down to well-consolidated earth, it may be said that motors of 10 h.p. and under can be mounted direct on a sound concrete workshop floor (or on a floor of brick mounted on and bedded in concrete), some 3 to 4 in. thick, while for larger powers, average figures may be taken as :

H.p.	*Inches Deep*
10–25	6–8
25–50	8–10
50–75	10–15
75–100	15–24

These figures are the depth of the foundation block below the earth line, i.e. the buried portion. The height of plinth must be added to these to obtain the overall depth of the block, and here consideration must be given to the alignment of the drive and to the grouting allowance which must be left between the bottom of the feet, bedplate, or slide-rails, and the top of the finished plinth. These matters are dealt with later in their appropriate sections. Further, they assume well-rammed earth both below and around the foundation block, and average drives, free from abnormal belt pull, etc., and free also from shock loading. For larger powers, special drives, and conditions where shock and vibration are to be encountered, the motor makers should be consulted.

Consult the Local Surveyor

When any doubt is felt as to the carrying capacity or nature of the earth upon which it is proposed to erect the foundations, the local surveyor should be consulted. For cases where solid ground cannot be reached, the foundations must be large enough to support the weight of the machinery, and the force of drive, such as belt or chain pull, and the actual dimensions necessary must be worked out in each case from an actual knowledge of the nature and capacity of the soil.

In some few cases it is possible to mount the motor direct on solid rock, and this, provided the rock is sound and trimmed off level, is quite permissible, of course, the foundation bolts being grouted into suitable holes cut into the rock and a concrete facing being provided if necessary from the nature of rock or appearance point of view.

To place the motor in position, the best procedure is to mount it upon its bedplate or slide-rails and to insert each foundation bolt in the bed or slide-rail provided for it, placing the nuts in position so that the bolts hang down. The machine is hoisted up on a crane, or a block and tackle are employed to allow this to be done. The whole assembly of motor, slide-rails, and foundation bolts is now lowered into the foundation block, each foundation bolt entering the pocket prepared for it, and the rough alignment is carried out as described later.

When this is completed, the foundation bolts are grouted in, and to do this we must prepare a mixture of one part cement by volume with two parts sharp sand (again not seashore sand), intimately mixing these ingredients in the dry state and then adding sufficient water to make a thick paste which will just pour. Only sufficient of this should be made at one time to fill one foundation-bolt pocket, and after seeing that the bolt is central in the slide-rail hole—a very important point—the mixture is fed into the pocket until it is completely filled. This grouting may be lightly trowelled into place to consolidate it.

In order to fill the foundation pockets in this manner it may be necessary to lift the machine slightly, and here it may be said that when aligned, and before grouting in the bedplate or rails, there should be a

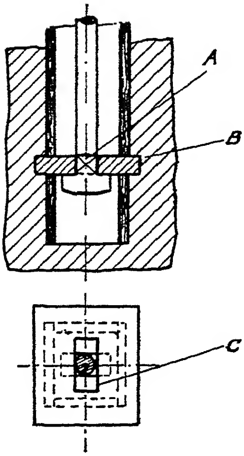


Fig. 1.—A SIMPLE TYPE OF REMOVABLE FOUNDATION BOLT

A is a square on the bolt; *B*, plate; *C*, slot in plate.

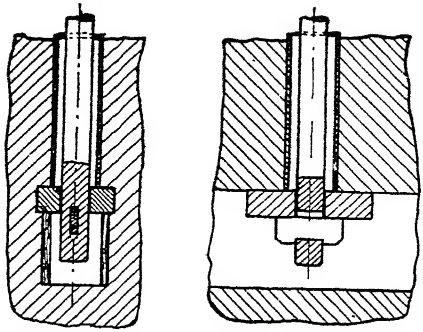


Fig. 2.—ANOTHER TYPE OF REMOVABLE FOUNDATION BOLT

Bolt has cotter through end. Foundation has armhole.

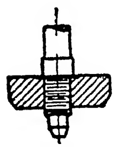


Fig. 3 (*left*).—FOUNDATION BOLT AND PLATE THREADED

space of about $\frac{1}{8}$ in. to $\frac{1}{4}$ in. between the top of the concrete block and the underside of the bed. This space is to allow for grouting in the bed-plate or slide-rails.

Each foundation bolt should be grouted in as described and should then be left until the grout is thoroughly hardened.

Many foundation bolts are concreted or cemented in place, with no idea of removing them. In other cases, it is very desirable to be able to remove them in case of breakage or alterations.

Fig. 1 shows a foundation bolt end not built in the concrete, but capable of removal.

To remove the bolt it is only necessary to lower it, until the square A comes below the plate B. It can then be turned round 90° until the head of the bolt will pass into the slot C. It can then be pulled right out of the hole.

Fig. 2 shows a foundation bolt having a cotter instead of a head. To remove the bolt it is necessary to lower it and push the cotter out, when the bolt will be free and can be raised out of the hole. In this case the foundation must have an armhole to be able to reach the cotter from the side.

A foundation plate which is threaded to take the end of the bolt is shown in Fig. 3. It is better in this case to have a good lead on the

end of the bolt, to find the hole in the plate easily. It needs screwing up tightly against the small shoulder shown.

This type is not so good where there is vibration, as it is then liable to work loose.

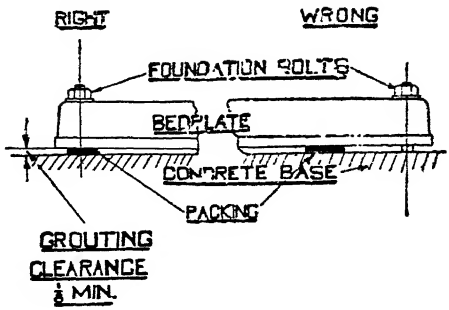


Fig. 4.—PACKING UP A BEDPLATE FOR GROUTING IN

Showing right and wrong ways of providing ⅛-in. grouting clearance. Note that on left the packing is placed as close as possible to foundation bolt. The wrong method (on right) will result in bedplate being bent or distorted when foundation bolts are tightened down. The packing should consist of sheet iron or sheet steel, not wood.

Grouting in the Bedplate

After the foundation-bolt grouting is set, we are ready to fix the bedplate or slide-rails in their permanent position and grout them in.

In order to do this we must pack up the bedplate rails or feet to provide the grouting allowance of ⅛ in. minimum, and the right way to do this is to use packing of sheet iron or steel (not wood) and place this packing close to the foundation bolts as shown in Fig. 4. If the packing is placed away from the positions of the bolts, the bedplate will be distorted or bent when these are tightened down, and this must be avoided at all costs or trouble will ensue. The packing must be adjusted and the bedplate moved slightly up, down, or sideways until the alignment is perfect, as described in the notes given later. Note that when perfect alignment has been obtained with the foundation bolts tightened hard down there must still be a space of at least ⅛ in. between bottom of bedplate and top of concrete block. This space will be filled in with the grouting mixture.

Having got the alignment correct and checked it, as described later, the grouting may proceed. For this a wooden frame is prepared, leaving about 1 in. space between the inside of the frame and the outside of the bedplate all round; suitable timber is 1 in. square, and the frame may be built up of strips of this size, or, if the bed is of complicated shape, the strips may be built up around it so that the 1-in. clearance is maintained. The strips may be lightly nailed together at the corners.

Next, a mixture must be made exactly as for the foundation-bolt grouting (one cement, two sand), enough being prepared to complete the job at one pour. When all is ready, the grout may be poured in and well trowelled into the space between foundation and bedplate, the job being completed by filling up the space between frame and bedplate until the mixture is level with the top of the framing.

Final Notes on Foundation Work

When this grouting has set hard, the framing may be removed and the concrete trimmed up to present a finished appearance. The foundation bolts should be pulled down as tightly as possible and the alignment checked over once more. With a properly designed and carefully constructed foundation it will be found that the lining up has remained perfect, and it will continue to be so throughout the life of the machine, with the result that the drive will always be smooth and vibration-free and maintenance will be minimised.

Alignment

We now come to the question of alignment, and at the outset it must be understood that this is perhaps the most important aspect of installation work. Imperfect alignment will always result in trouble with bearings, shafts, and drive details generally.

Before the foundation bolts are grouted in, the alignment must roughly set, so that, by taking up the clearances in the foundation-bolt holes, we may make the lining up exact. This may usually be done by eye in the case of solid and flexibly coupled and gear drives, but for belts and chains it will be necessary to use straight-edges and lines as described later.

DIRECT-COUPLED DRIVES

Solid and Flexible Couplings

A coupling is in line when the centre lines of driving and driven shafts coincide, and exact alignment is absolutely essential for both solid and flexible couplings. The solid or rigid type of coupling should be used only for very large jobs, or for cases where the driving and driven machines are mounted on a common bedplate, because it requires extremely accurate alignment ; further, it should not be employed to couple together a machine with ball or roller bearings to one with sleeve bearings, since in all these cases the rigidity of the coupling will result in strains on shafts or bearings or both, and trouble is sure to result.

In all cases possible, a flexible coupling should be employed, and undoubtedly the best variety is one of the all-metal type, although excellent service will be given by other forms if correctly applied. Departure from perfect alignment in flexibly coupled drives, if not of large amount, will not result in undue strains on shafts or bearings, but it will cause the coupling to wear and shorten its life, so that, even if a flexible coupling is employed, perfect alignment is most important.

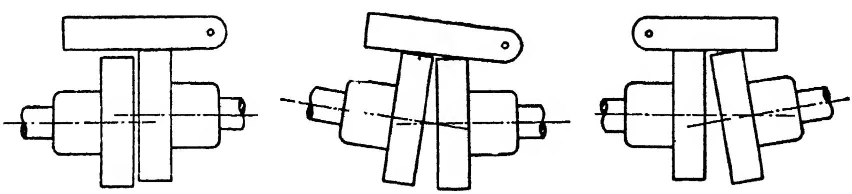
A further point to watch is that with solid couplings only one of the shafts, either driver or driven, must be located endwise, so that if it is proposed to use this type of coupling the motor makers must be informed,

when ordering the machine, where the location is to be situated, and if it is required in the motor they must be told the end-thrust to be carried due to the driven machine. This does not arise in the case of flexibly coupled drives, although if the end-play of the driven shaft is large, its value should be stated to the coupling makers or suppliers, so that it can be accommodated and the correct type of coupling put forward.

Aligning Couplings

The exact aligning of couplings, before final grouting in, may be effected as follows. The foundation-bolt grouting having set hard, the bolts are tightened down so as just to nip the bedplate, the packing (at least $\frac{1}{8}$ in. thick) being between the lower face of the bedplate and the top of the concrete foundation pad. A check should now be made that the centre heights of motor and driven machine are identical, and that the shaft centre lines coincide by placing a straight-edge (such as a steel rule) across both coupling flanges.

If all is correct, the rule will make full contact across both coupling flanges, whereas, if the couplings are on the same centre but one shaft is inclined to the other, or if one shaft is lower than the other, the contact between coupling flanges and straight-edge will occur only at one of two points, or on one flange only, as shown in Fig. 5. If this happens. the bedplate must be packed up or let down as necessary, taking care to preserve the $\frac{1}{8}$-in. grouting clearance, until full contact is attained, and then the horizontal alignment may be checked in a similar manner by placing the rule on the sides of the coupling flanges and adjusting the position of the motor in a horizontal plane until full contact is obtained.



Shafts are parallel but out of centre.

Couplings are on same centre but shafts are inclined to each other.

Shafts both inclined and out of centre.

Fig. 5.—Lining up couplings

The two half-couplings are here shown in various stages of mal-alignment, and out of centre, and a straight-edge is shown across the flanges in each case. The lack of alignment is at once obvious when the contact between straight-edge and *both* coupling flanges is inspected. Note also how the distance between the two coupling faces differs at the top and bottom edges in those cases where the shafts are inclined to each other.

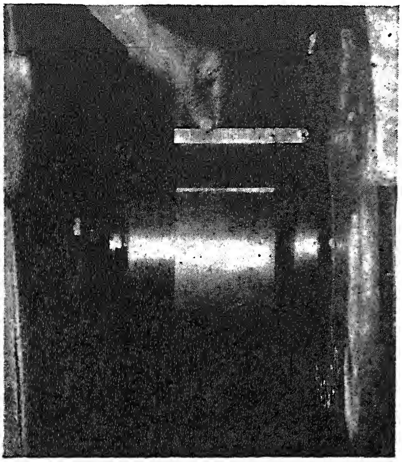


Fig. 6.—Aligning couplings (1)

A straight-edge placed across the coupling flanges makes full contact only when the shafts are in line, always providing that the flanges are of exactly the same diameter. (*Metropolitan-Vickers.*)

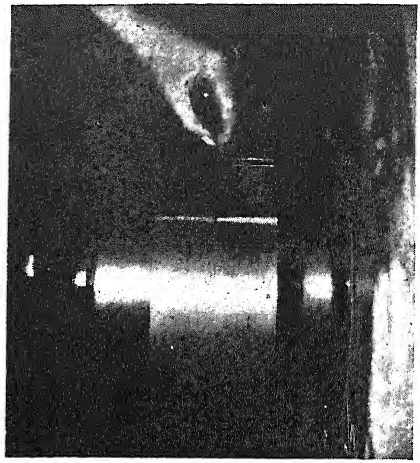


Fig. 7.—Aligning couplings (2)

The distance between the coupling faces should be measured by a feeler gauge at four points 90° apart. If all four measurements are equal the shafts are in line. (*Metropolitan-Vickers.*)

How to Tell when Completely Aligned

When alignment appears perfect by the above method, the foundation bolts are tightened hard down and a check is made by straight-edge as before, to ensure that this tightening has not altered it. If necessary, any small adjustments are made, and alignment check is now made by placing the straight-edge at four points, 90° apart, in contact with the coupling flanges, and if full contact is obtained at each of the four positions we may proceed to measure the distance between the coupling faces by means of a feeler gauge. This distance should be measured at four points and complete alignment is attained when—

(1) A straight-edge gives full contact with both coupling flanges at all four points round the shaft, each point being 90° from the other.

(2) The distances between the coupling faces, measured by feeler, is the same, also at four points 90° apart.

Adjustment of motor position must be made until both these conditions are satisfied, the foundation bolts being pulled up as tight as possible, and when all is in order, the final grouting may be carried out as previously described. When this has set check over the alignment again, and if correct fit the coupling bolts. The installation may now be turned round a few revolutions by hand to ensure that everything is in order

Final Notes on Coupled Drives

In making all the measurements described in the foregoing notes, neither motor shaft nor driven shaft should be revolved until the last check immediately prior to final grouting. Then the motor shaft should be turned half a revolution in one direction and the driven shaft half a revolution *in the other direction*, and the check should be made. If it now appears that the alignment has altered, one or the other of the shafts is bent, or some eccentricity exists, and it is absolutely essential that such conditions be rectified before proceeding further or else trouble will result on the final drive.

A further point to watch is that the shafts should be level, unless special provision has been made to carry the thrust due to out-of-level conditions. This point should be watched at every stage of the lining up, being checked by spirit level and all adjustments made so as to ensure that the level is maintained. It is, of course, futile to endeavour to maintain a level motor shaft when the driven shaft is not level, and in this case the correct thing is either to level up the driven machine or if this cannot be done, inform the motor maker that the shaft will be out-of-level. A slight out-of-level is not usually important when the motor is fitted with ball bearings, but for roller- or sleeve-bearing cases some provision must be made to cover it.

BELT DRIVES

A belt drive is in correct alignment when the centre lines of driving and driven shafts are parallel and when the centres of both pulleys are on the same line. It is also necessary to ensure that the pulleys are the correct distance apart so as to obtain the correct belt tension, and for this reason motors intended for belt drive are usually mounted on slide-rails or a slide-base.

In lining up a belt drive one should first ensure that the shafts are level, and then the pulleys should be placed in position but not finally keyed up. The pulleys should be as close to the bearings as possible, so as to avoid strains on the shafts due to belt pull, and for motors larger than about 75 h.p. it is necessary to employ an outboard bearing, so as to obtain support at both sides of the pulley.

The pulleys themselves should be correctly balanced and should be of the crowned-face type, and it is good practice to limit the diameter of the larger pulley to six times the diameter of the smaller one, while the centre distance between the two shafts must not be less than four times the diameter of the larger pulley, unless a jockey pulley or similar device is employed.

Vertical Drives should be Avoided

It is bad practice so to arrange a plain belt drive that the driven pulley is directly above or below the driver. Such drives invariably

give trouble due to belt slip, unless excessive belt tension is employed.

Belts and Belt Adjustment

The usual types of belting are leather and balata, and Figs. 8–9 give the horse-power per inch of width for each of these types, so that it is possible to calculate the required width of belting for any particular drive. The maximum speed at which the belting should be run is 5,500 ft. per minute, and the pulley diameters must be calculated with this maximum figure in view, at the same time bearing in mind that it is advisable, in the interests of the belt life and sweetness of drive, to keep the belt speed below 4,500 ft. per minute if possible, since drives at higher speeds tend to be noisy and harsh.

The belt joint must be smooth and free, and it is preferable to obtain an endless belt of the correct size for the drive. These endless belts are produced by several manufacturers, and are undoubtedly the best proposition as regards silence, life, and freedom from vibration, but, if a jointed belt is to be employed, the joint must not bind in any way. The belt itself must be flexible, so as to bend over the pulleys without undue effort.

The belt tension is a most important point : when the motor is running with the belt correctly adjusted, full load should be carried without the belt slipping, and there should be no flapping on the slack side, else the belt will soon be damaged. At the same time, the belt when stationary should not feel board hard. Both excessive and too little belt tensions are harmful, the first leading to broken or bent shafts and damaged bearings, while the slack drive is noisy and dangerous, since the belt may break or come off and hit workpeople in the vicinity.

Jointing and Fitting Belts

When an endless belt is not employed and a length of belt is to be joined up, the two ends must be cut absolutely square and the joint or lacing made secure, bearing in mind that it will be subject to the full belt pull. The correct method of fitting the jointed belt is to move the motor on its slide-rails as close to the driven shaft as possible, and then place the belt on both pulleys, subsequently adjusting the slide-rails to obtain the correct belt tension. The belt should never be forced on to the pulleys, since this causes stretching of one side, which leads to bad running and short belt life.

As stated before, pulleys should be fitted close to the bearings, and it follows that with fast-and-loose drives the fast pulley must be next to the bearing so as to avoid trouble due to belt pull on a long shaft overhang. For the same reason the pulley should not be of too small a diameter, since the belt pull increases as the diameter of pulley decreases.

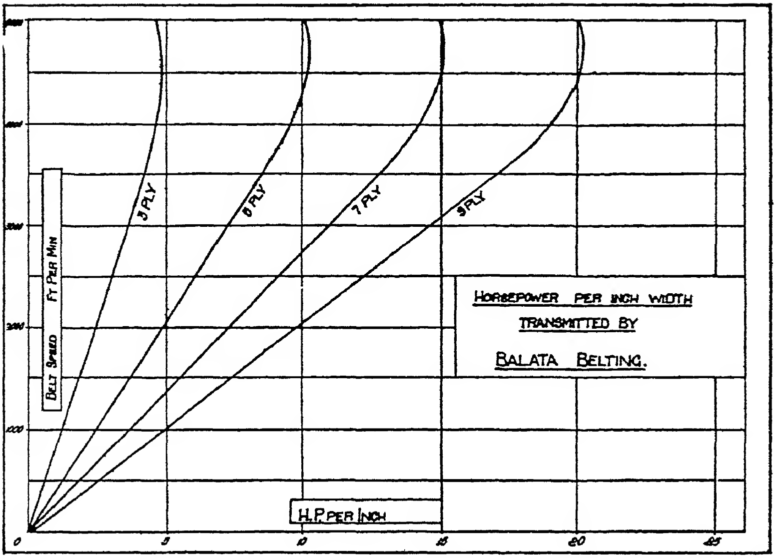


Fig. 8.—CURVE SHOWING BELT H.P. WITH BALATA BELTING

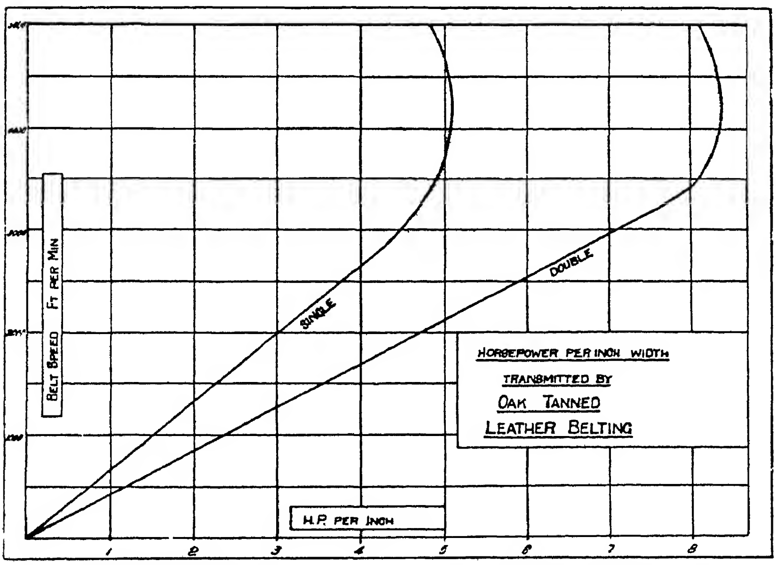


Fig. 9.—CURVE SHOWING BELT H.P. WITH OAK-TANNED LEATHER BELTING

It is only by consulting the motor maker that the minimum permissible pulley diameter can be ascertained, and this should be done in all cases of doubt, although it is safe to say, as a starting-point, that any pulley larger than the one shown on the motor outline drawing will generally be in order. Smaller-diameter pulleys must be approved or the motor manufacturers cannot be expected to take responsibility for broken or bent shafts or damaged bearings.

Calculating Belt and Pulley Sizes

Let us now calculate the belt and pulley particulars for a 20-h.p. motor running at 1,000 r.p.m. which is to drive a lineshaft at about 250 r.p.m. by means of a belt.

The first point to settle is the belt speed, and this may be taken at 3,000 ft. per minute in order to make a start. A belt speed of this order will give a good drive, and it is good average practice for main-belt drives. The motor-pulley diameter, in inches, will then be—

$$\frac{\text{Belt speed} \times 3{\cdot}8}{\text{Motor r.p.m.}} = \frac{3{,}000 \times 3{\cdot}8}{1{,}000} = 11{\cdot}4 \text{ in.}$$

This would be rounded off to $11\frac{1}{2}$ in. The size of lineshaft pulley would be, using the same formula—

$$\frac{\text{Belt speed} \times 3{\cdot}8}{\text{Lineshaft r.p.m.}} = \frac{3{,}000 \times 3{\cdot}8}{250} = 45{\cdot}6 \text{ in.}$$

And this again would be adjusted, in practice, to $45\frac{1}{2}$ in.

We must now fix the pulley-face width as follows: On referring to the curve, we see that at 3,000 ft. per minute a single oak-tanned leather belt will transmit 4·5 h.p. per inch of width. Now, the horse-power of the motor is 20 and a motor of this size will carry 25 per cent. overload for 2 hours, and this overload should be allowed for in calculating the belt width, so that we work on a basis of $20 \times 1{\cdot}25 = 25$ h.p. The belt width will therefore be—

$$\frac{\text{Horse-power load (max.)}}{\text{Horse-power per inch}} = \frac{4{\cdot}5}{25} = 5\tfrac{1}{2} \text{ in.}$$

which we would round off to 6 in.

The pulleys should be about 1 in. wider than the belt, so that in our calculation we would make both pulleys at least 7-in. face, and furthermore the pulleys should be slightly larger in diameter at the centre than at the edge. This is termed crowning, and a good value is $\frac{1}{4}$ in. per foot of pulley face; that is to say, a pulley of 12-in. face and 11-in. diameter at the centre would be $10\frac{3}{4}$ in. in diameter at each of its edges, tapering regularly from the centre on each side. This crowning is independent of the diameter.

Crowning

In the case of our example the crowning will be—

$\frac{\text{Pulley face}}{12} \times$ crowning per foot $= \frac{7}{12} \times \frac{1}{4} = 0{\cdot}146$ in., which we would make $\frac{1}{8}$ in. (0·125 in.) for practical purposes. The minimum centre distance for this drive will be—

$$\text{Centres of pulleys} = \text{diameter of large pulley} \times 4 = 45\tfrac{1}{2} \times 4$$
$$= 182 \text{ in., say, } 15 \text{ ft.}$$

The larger pulley is $\frac{45\frac{1}{2}}{11\frac{1}{2}} = 3{\cdot}95$ times the diameter of the smaller one, so that the drive satisfies the rule that the larger pulley must not be more than six times the diameter of the smaller one, and we will have a satisfactory drive.

Summarising our calculations, we have—

Motor pulley . . .	$11\frac{1}{2}$ in. diameter $\times$ 7 in. crowned face
Lineshaft pulley . .	$45\frac{1}{2}$ in. diameter $\times$ 7 in. crowned face
Belting	6 in. wide, oak-tanned leather, single
Minimum centre distance	15 ft.

Jockey or Rider Pulleys

If, in the above example, practical considerations had demanded that the centre distance be less than four times the diameter of the larger pulley, or that the ratio of the pulley diameters be more than 60, we would have had to consider using a jockey or rider pulley. This device is fitted close to the smaller pulley so as to increase the arc of contact between belt and pulley and so permit of a satisfactory drive without excessive belt tension.

Shaped-belt Drives

For cases where the centre distance is small or the speed ratio high, and where high load capacity is demanded, shaped-belt drives have a large sphere of application. There are several proprietary makers of this type of drive, and the manufacturers have in each case produced a table of loadings giving the capacity of their product. For this reason it is not possible to give particulars here, but it may be said that, in general, drives of this type employ endless belts of special shape running in grooved pulleys, several such belts being employed in parallel, depending on the power to be transmitted. These drives are very popular for individual machine-tool applications, and when space is limited or the adverse conditions mentioned above apply, it will pay to consult the manufacturers. The lining up will follow the same general lines as for plain-belt drives, to be described later.

CHAIN DRIVES

Here again, the chain manufacturers should be consulted in each individual application. Chain drives give a positive, silent, high-

efficiency drive of long life, and the following general factors may assist in the preliminary considerations of this method of power transmission.

With the correct arrangements there is practically no centre-distance limitation for chain drives, but it is good practice to make the centres between driving and driven shafts about 45 chain pitches, that is to say, with a 1-in. pitch chain a good centre distance would be 45 in. As regards ratio, it is not advisable to have more than 120 teeth in the large wheel, while the pinion should have not fewer than 19 teeth, or 17 teeth in certain special cases. This means that the speed ratio will not usually be greater than $\frac{120}{19} = 6{\cdot}3$, or in special cases $\frac{120}{17} = 7{\cdot}06$.

The chains and wheels must be well lubricated and are usually enclosed in gear cases for this purpose, while the lining up follows the same general procedure as for belt drives. The selection of a correctly proportioned chain drive is a matter which should be left to the makers, and they should be consulted when such an arrangement is contemplated.

ROPE DRIVES

Drives employing cotton ropes running in grooved pulleys are very popular in the textile trades, and they are capable of transmitting large powers smoothly and sweetly, while the ropes have a long life when correctly installed. Ropes usually vary between $\frac{3}{4}$ in. and 2 in. in diameter, while the rope speed lies between 2,000 and 6,000 ft. per minute, 3,000 ft. per minute being a good average, the horse-power per rope at this speed being, for good-quality cotton ropes, approximately as shown in Table I. The grooved rope pulleys are usually made of cast iron, and the effective diameters required (the effective diameter is measured at rope centre line) may be calculated as for an ordinary belt drive with the qualification that the pulley must not be too small for the diameter of rope employed. The minimum pulley diameter, for ropes running at 3,000 ft. per min., expressed in rope diameters, is given in Table II, and as an example, the minimum advisable pulley diameter for a $1\frac{1}{2}$-in. diameter rope running at 3,000 ft. per min. would be 25 rope diameters, or $1\frac{1}{2} \times 25 = 37\frac{1}{2}$ in. The makers of driving ropes should be referred to when it is proposed to install a rope drive. Lining up is on the same basis as for belts, described later.

TABLE I—COTTON DRIVING ROPES

Rope Diameter (Inches)	*H.p. per Rope (at 3,000 Ft./Min.)*	*Rope Diameter (Inches)*	*H.p. per Rope (at 3,000 Ft./Min.)*
$\frac{3}{4}$	7·0	$1\frac{3}{8}$	23·5
$\frac{7}{8}$	9·5	$1\frac{1}{2}$	27·5
1	12·0	$1\frac{5}{8}$	32·5
$1\frac{1}{8}$	15·5	$1\frac{3}{4}$	38·0
$1\frac{1}{4}$	19·0	2	49·5

TABLE II.—PULLEYS FOR ROPE DRIVES

Rope Diameter (Inches)	*Minimum Pulley Diameter, in Rope Diameters*
$\frac{3}{4}$, $\frac{7}{8}$	20
1, $1\frac{1}{8}$	22
$1\frac{1}{4}$, $1\frac{3}{8}$	24
$1\frac{1}{2}$, $1\frac{5}{8}$	25
$1\frac{3}{4}$, 2	30

GEAR DRIVES

There are numerous types of gear drives which may be employed, but in every case the motor maker should be informed that it is proposed to use this type of drive so that the shaft and bearings may be proportioned accordingly. Spur gearing is common, and may be employed for speed ratios of not more than 6 : 1, while good practice limits the pitch-line velocity to not more than about 1,000 ft. per min. Rawhide, paper, and fabric pinions may be employed in the interests of silence and resilience of drive.

Gears which give rise to thrusts, such as single helicals or bevels, must never be used without consulting the motor maker. It is therefore necessary for the makers to be informed.

The designing of a gear train is a specialist's work, and for this reason the reader should consult a gearing manufacturer before deciding on the type and size of gear to be employed.

Alignment of spur and helical gears may be carried out as described later; worm gears, bevels, skews, and other special types will usually be enclosed in special gearboxes to which the motor will be direct-coupled. The procedure for alignment of direct-coupled drives with solid or flexible couplings has already been described.

ALIGNMENT OF BELT, SHAPED-BELT, ROPE, CHAIN, AND GEAR DRIVES

In all these drives, alignment is achieved when (*a*) the driving and driven shafts are parallel to each other, and (*b*) the centre lines of pulleys or pinions coincide, and to ensure these conditions the following procedure should be followed. The motor should be mounted on its bedplate or slide-rails and the foundation bolts should be fitted in the holes provided for them, after the motor has been hoisted up, as described for direct-coupled alignment.

The complete equipment is then lowered on to the foundation; each

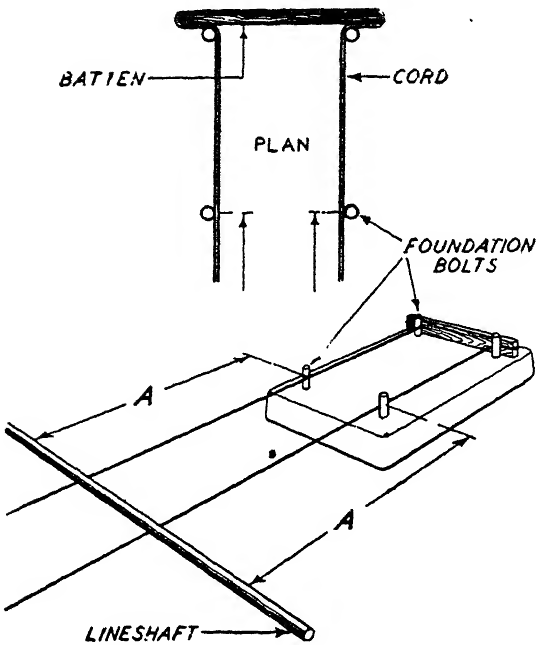


Fig. 10.—Using a lining-up cord for aligning belt, rope, chain, or gear drive

This shows a method of ensuring that measurement (*A*) is taken along line at right angles to the motor centre line. If the measured distances (*A*) are the same, the shafts are in line. The cord (or wire) is stretched tightly between the motor foundations and supports some distance beyond the lineshaft. The sketch shows a very convenient method of using the cord.

foundation bolt being placed in the pocket provided for it, the grouting clearance of $\frac{1}{8}$ in. between top of foundation and bottom of bed or slide-rails being maintained as previously described, measuring the distance between them at two points as far apart as possible, and adjusting the position of motor until the two distances are equal. For instance, in the case of a motor driving a lineshaft, we would measure the distances from the motor-shaft centre line to the lineshaft, first at the free end of the motor and then at the pulley end, taking care that the measurements are made along a line at right angles to the motor shaft.

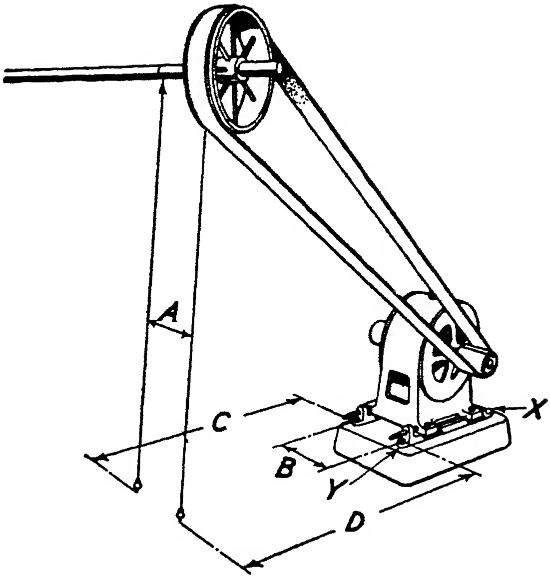
In order to ensure this, it is a good plan to use the bolts in the motor feet in conjunction with the cords or wires as shown in Fig. 10. If the measurements are equal the shafts are parallel; if not, the motor must be moved to make them so. A steel rule or tape should be employed for all measurements, since tapes or strings are liable to stretch and give incorrect results.

If the Shafts are not Level

When the levels of the motor and driven shafts are different, it is usual to employ two plumb lines suspended from the higher shaft, marking the positions taken up by the plumb-bobs at the level of the lower shaft. The distances between these markings and the centre of the lower shaft are measured as before, equality indicating that the shafts are parallel. If the lineshaft is higher, the plumb lines are fixed

Fig. 11.—ALIGNING A BELT DRIVE

For true alignment between the shafts the distances *C* and *D* must be equal. Note that the measurement of *C* or *D* must be made on a line at right angles to the motor shaft. The easiest way to ensure this is to measure along a straight-edge which is laid across the centres of the foundation bolts of each slide-rail, i.e. bolts *X* and *Y*. In other words, the plumb bob, bolt *X* and bolt *Y* must lie on a straight line. Distances *A* and *B* should of course be equal and this can be ensured by using the lining-up method illustrated in the next Fig. A steel rule or tape should be used in taking measurements.



to it separated by a distance equal to the space between the motor holding-down bolts, while in the event of the motor being above the driven shaft, the lines would be attached to its holding-down bolts. The principle to be followed will be clear from Fig. 11.

Lining up the Pulleys

Having made the shafts parallel we must satisfy the second condition that the centre lines of driver and driven pulleys coincide, and the method of doing this depends on the distance between them. If the pulleys are fairly close, say, not more than 20 ft. apart, a rigid wooden or steel straight-edge may be used so placed that it makes contact with *both* edges of *both* motor and driven pulleys (if the pulleys are of equal face) as shown in Fig. 13. The position of the pulleys should be adjusted until all four contacts are obtained, taking care not to move the motor so as to upset the parallelism while doing this, and the drive then aligned.

Should the pulleys be of different face width, the straight-edge may still be employed, being placed so that it is in contact with both edges of the *wider* pulley and the distances from the straight-edge to the centre of the narrower pulley being measured at the two points diametrically opposite on the narrow pulley where the straight-edge is nearest to the pulley edge, i.e. where contact would be obtained if the pulleys were of equal width. These two measurements must be equal, and must be the same as half the width of the wider pulley for alignment to be correct.

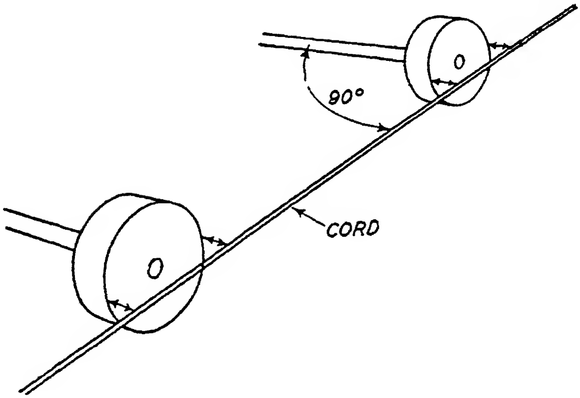


Fig. 12.—ALIGNING PULLEYS—CORD METHOD

The cord is stretched at right angles to one of the shafts and in a position a few inches from the edge of the pulley. The position of the second shaft and of the pulley upon it is then adjusted, so that the four dimensions shown arrowed are equal, and the pulleys are then truly aligned.

When the shafts are too far apart for this method to be utilised, a lining-up cord is suspended (*at right angles to the shafts*—this is important) from points some little distance beyond the outer edges of both pulleys, and measurements are then made from the cord to the edges of pulleys, in the case of equal widths, as shown in Fig. 12, or from cord to centres of pulleys for unequal faces. When all four measurements are equal, the drive is aligned.

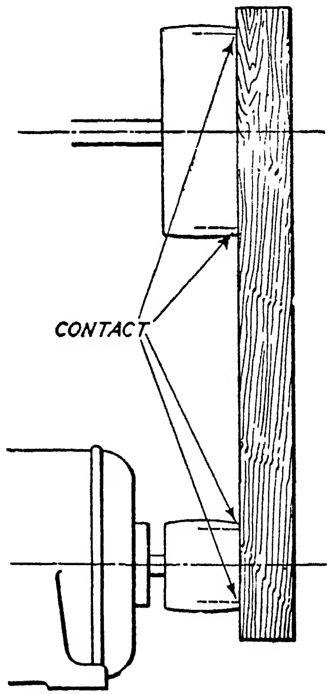


Fig. 13.—ALIGNING PULLEYS—STRAIGHT-EDGE METHOD

The straight-edge is placed so as to make contact with both pulleys at two points at opposite ends of diameter in each case. If pulley faces are unequal the cord method (Fig. 10) should be used and centre of pulleys aligned.

Grouting In

Having lined up as described, the foundation bolts may be grouted in. When set hard, they may be pulled up and alignment checked, and if all is in order, the bedplate or slide-rails may be grouted as previously described, checked, and trimmed, and the drive is then ready for service.

Final Notes on Alignment

The above notes refer primarily to belts. For ropes or shaped belts the pulley-groove centre lines must be employed in place of the edges or centres of pulleys, while for chains the chain

centres of sprockets and wheels must be used. In the case of chains and gears alignment must be perfect or breakdown will quickly result, and here the correct centre distance is most important for correct meshing, while the wheels and pinions must be perfectly true on their shafts.

Slight misalignments of plain belts will result in incorrect running and poor belt life. If the shafts are not parallel the belt will run off, or it will run to the side of the smaller pulley if the out-of-parallel is not great; while if the shafts are parallel but the pulleys not in line, the belt will run to one side of the larger pulley.

Finally, after having lined up, the drive should be turned over slowly, by hand if possible, feeling for any resistance or jerkiness. In the case of large drives, where hand turning is impracticable, the motor should be run at low speed and the ammeter watched for any increase of current which indicates a tight spot. All such inequalities must be eliminated before putting the drive into service; a final check of alignment should always be made after tightening up the foundation bolts, since this final tightening often produces slight misalignments.

Chapter VI

INSTALLATION OF LINE SHAFTING

HAVING ascertained the size of shaft required, survey the place where the shaft is to be fitted, to see what fixtures will be required.

In the majority of cases shafting is carried by brick walls, the brackets being held by bolts passing through the walls and having large plates on the back to spread the strain over a considerable area of the brick-work (Figs. 1, 4, and 4A).

Thickness of Walls to Support Shafting

Shafting should not be fitted on any wall under 9 in. in thickness. Very light shafting, up to $1\frac{1}{2}$ in. diameter, is occasionally fitted on $4\frac{1}{2}$-in. walls, but it is not advisable unless the wall is braced at the back with wood or iron plates to distribute the load. Over 2 in. diameter, walls of 14 in. thickness are necessary. In each case it is presumed that the shafts will be carrying their normal loads.

Ordering Shafting and Other Equipment

The length of shaft being determined, it can be ordered in suitable lengths with the necessary couplings, plummer block, and brackets. The size of the largest pulley which the shaft will have to carry will determine the projection of the bracket from the wall (Fig. 1).

Marking Out Wall for Shafting

A wood template should be made of the brackets giving the bolt holes and the position of the centre of the shaft from the wall and also the height of the shaft from the top of the bracket, Fig. 2. A long wood straight-edge, which may consist of a well-seasoned board 1 in. $\times$ 6 in. planed on both edges quite straight and parallel, will be required. This should be long enough to more than span the spacing of the brackets.

Mark Position of Shafting

The height of the shaft centre is marked on the wall, and the bottom edge of the straight-edge is set to this, and a spirit level set on the top edge, the board being held at both ends. When the board is quite level, the line of the bottom edge on the wall is marked. The board is then moved along the wall and the line continued in the same way.

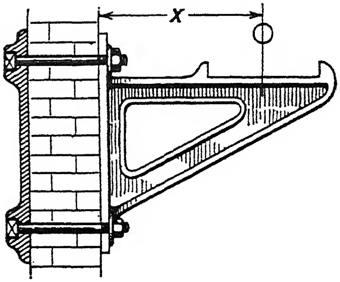


Fig. 1.—How wall plates are used to secure brackets on walls

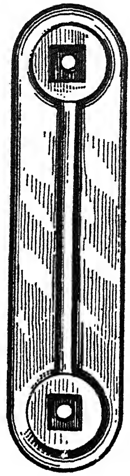


Fig. 4.—Wall plate for bracket in Fig. 1

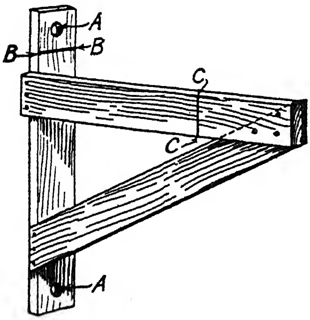


Fig. 2.—Wood template to give position of brackets on wall

The holes *AA* coincide with holes in back of bracket. The line *BB* gives the centre line height of shaft and the line *CC* the projection.

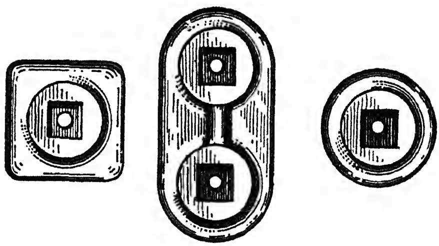


Fig. 4a.—Various types of wall plates

Fig. 5 (*above*).—Wall drill

It is rotated while being struck by hammer and it cuts a clean hole through a wall with no disturbance of brickwork.

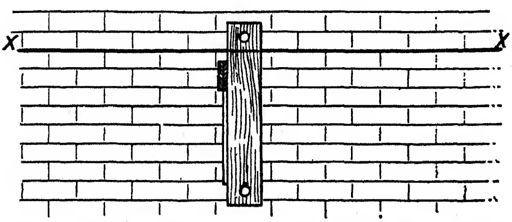


Fig. 3.—Marking out position of brackets on wall

Template on wall with line *BB* in Fig. 2 set to centre line of shaft marked on wall *XX*.

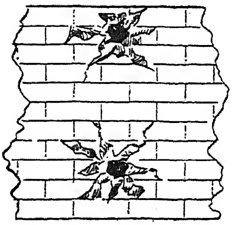


Fig. 6.—RESULT OF CUTTING BOLT HOLES THROUGH WALL WITH CHISEL

Chiselling fractures the brickwork and destroys the strength of the wall, even if the holes are filled with cement.

Marking Out Bracket Bolt Holes

The bracket template is then placed on the wall with the shaft centre line mark on the mark on the wall, Fig. 3, and the position of the bolt holes marked on the wall in the position the first bracket is desired to occupy. The position of the other brackets will then be measured off along the wall line and the template used as before to mark the bolt holes.

Drilling Bracket Bolt Holes

The holes were at one time cut through the wall with a chisel which had the effect of loosening and fracturing the bricks round each hole and destroying the strength of the wall so that cases were not unknown of the brackets pulling out, and the shaft collapsing with its pulleys, a very serious matter (Fig. 6). The bolt holes in the brickwork should be drilled with a wall drill, Fig. 5, which is turned by hand while being struck lightly with a hammer, and if reasonable care is used a clean hole can be drilled through the wall without even cracking the plaster surface, if there is one.

Bolts and Wall Plates Required

Bolts of suitable size and length will be required to hold the brackets, due allowance being made for the thickness of the wall plates on the other side of the wall. If the load is likely to be heavy, a wall plate equal in length to the bracket should be used and all the bolts picked up (Fig. 4).

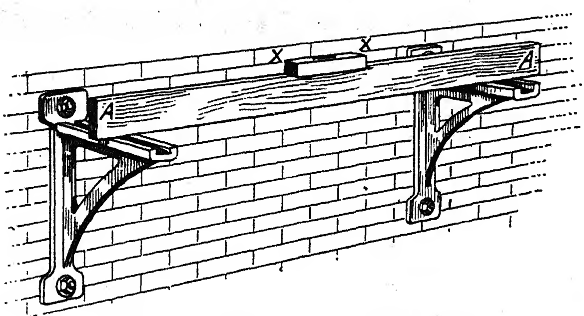


Fig. 7.—CHECKING LEVEL OF BRACKETS

Wood straight-edge *AA* laid on top of brackets with spirit level *XX* to get all same height.

Mounting Brackets on Wall

The brackets are now mounted on the wall and the bolts tightened enough to hold them firmly. The wood straight-edge is now laid along the tops of the brackets and, with the aid of a

spirit level, the brackets are all set to the same height, Fig. 7. The level is then put on the brackets and they are tested for level along their faces, Fig. 8. When level in both directions the bolts are tightened up finally.

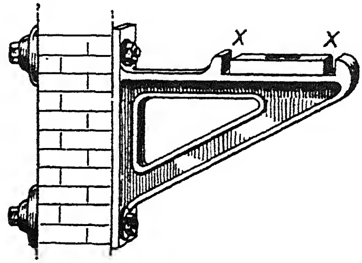


Fig. 8.—Spirit level laid on bearing seating to see that it is level

Mount Plummer Blocks

The plummer blocks are now mounted on the brackets and the bolts screwed up finger tight.

Laying the Shafting

The caps of the blocks are removed and the shaft is laid on the blocks. The couplings are then done up, the plummer blocks will allow the shafts to come into line as they are not tightened down.

Testing Shafting for Alignment

The shaft should be tested for level, and a smear of lampblack should be put on it at each block and the shaft turned. The blocks should be packed if necessary under the sides with strips of thin sheet steel, shimming steel it is termed, until the shaft is quite level and touches the brass of the plummer blocks equally over the whole length. The blocks should then be screwed down lightly and the level again tested. If in proper alignment a long length of shaft in plain bearings should be able to be turned easily by hand grip alone.

The caps of the plummer blocks should now be put on and bolted down and the shaft again tested for freedom.

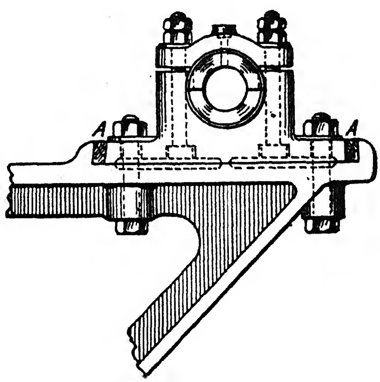


Fig. 9.—Fixing bearing block

When the position of block has been fixed, hard wood or iron wedges are driven in at *AA* to prevent block moving if bolts get slack.

Scraping Bearing to Ease Binding on Shaft

If any binding is found, test each cap with lampblack to find out where it is bearing on the shaft. Lineshaft bearings are seldom scraped in to the shaft, but are fitted as received except in cases of binding, when the high places may be eased by scraping.

Securing Blocks in Heavy Work

For heavy work, when the position of the plummer blocks has been

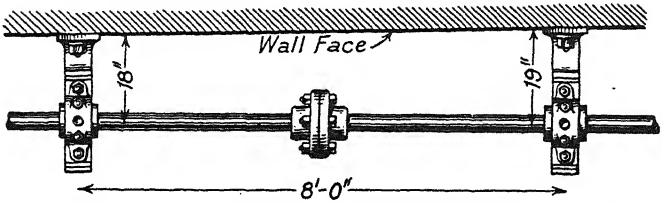


Fig. 10.—WHERE SHAFTING DOES NOT FOLLOW LINE OF WALL

If deviation is slight, brackets of different projection can be used, the holes in plummer block soles and brackets will allow blocks to stand slightly off square.

decided and the bolts done up tightly, hard wood or iron wedges are driven in between the ends of the plummer block soles and the feet cast on the brackets to ensure that the blocks cannot shift even if the bolts should get slack (Fig. 9).

If Shafting Leaves the Wall

Should the shafting not follow the line of the wall, it will be necessary to stretch a line, the height of the centre of the shaft or the top of the brackets, whichever is most convenient, to represent the line of the shaft. If the departure from the wall line is only a matter of inches, the case can be met by using brackets of a longer projection at the widest end, Fig. 10. If the departure is considerable, it may be necessary to fit columns made from steel joist, cemented into the floor, or bolted to floor joists according to circumstances and either bolted to the ceiling joists or carried by a return joist cemented into the wall, Fig. 11. If it is possible to carry the shaft by sling hangers, these can be used, but sometimes the floor or roof above is not suitable to carry the weight.

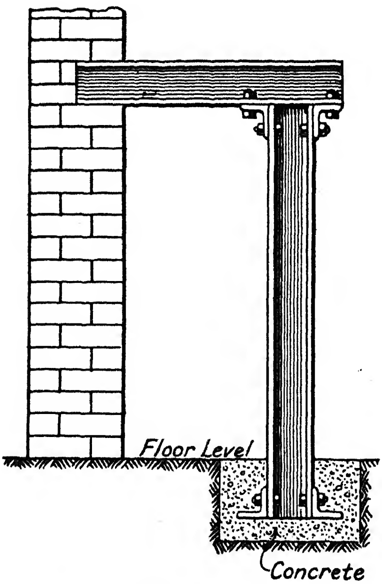


Fig. 11.—SHAFTING CARRIED ON STEEL JOIST WHEN IT IS NOT POSSIBLE TO USE THE WALL OR ROOF FOR SUPPORT

Carrying Shafting on Gantry

In many modern workshops where the roof is carried on bowstring or Belfast girders with no columns

available, the shafting is carried on a gantry made up from light steel joist, as in Fig. 12. The longitudinal joists allow the cross joists supporting the plummer blocks to be moved anywhere desired along their length. The vertical joists are either cemented in the floor, or bolted to floor joists if available.

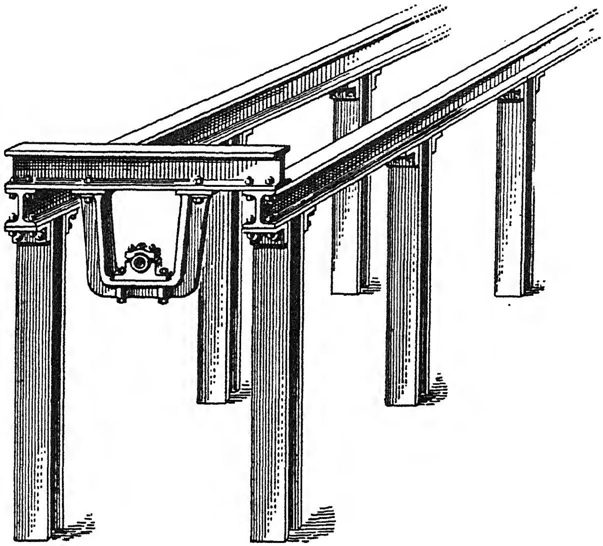


Fig. 12.—Shafting carried on gantry of light steel joists

Constructing Walls to Carry Shafting

When buildings are being erected, provision is made in the construction of the walls to carry the shafting, piers being formed in the brickwork where the brackets will go, if the shaft is to carry considerable power. The builders are provided with templates and leave slots in the walls to take the holding bolts, the erection of the shafting being much simplified.

Using Adjustable Bearing Fittings

Adjustable and swivel bearing fittings make the erection of shafting much easier than with the ordinary type as any little error in the height or level of the brackets can be adjusted by the screws either vertically or horizontally. The shaft still has to be levelled and lined up as with the fixed bearings.

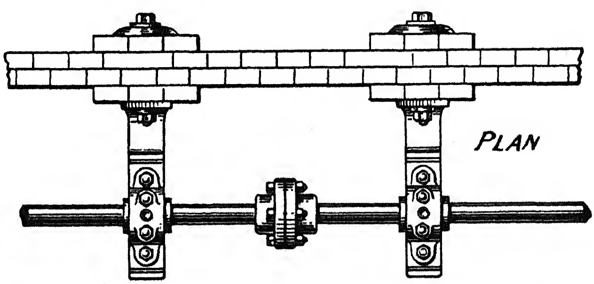


Fig. 13.—Wall built with piers to carry shafting brackets

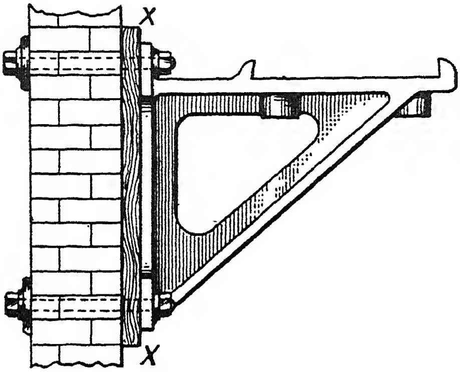


Fig. 14.—To give a level wall surface

Wood packing strips *XX* are sometimes used with wall brackets to give a level surface and better grip on the wall.

Installing Ball- or Roller-bearing Blocks

With ball- or the usual type of roller-bearing plummer blocks, the bearing has to be slipped over the ends of the shafts before they are put in place, as while the blocks are split, the bearings are not. The shaft with the bearings still loose is placed in the blocks, and when the couplings have been done up and the shaft is in place laterally, the locking ring of the bearing can be tightened up. Unlike the plain bearing, the shaft cannot be moved laterally once the bearing is in place and gripped on the shaft.

True Up Wall Face for Bracket

When any form of cast-iron bracket is to be fitted to a wall, the face of the wall must be quite level under the bracket face. This should be checked, and if the wall is not level it should be chipped away slightly with a chisel to remove the high spots.

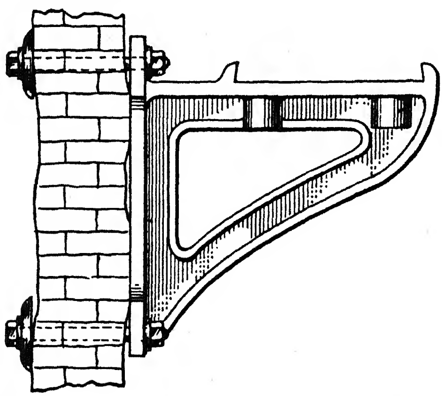


Fig. 15.—If surface of wall is uneven bracket may be fractured when bolts are tightened up

Using Wall Packing Piece

In many cases a wood packing piece is used between the wall and the bracket, an inch or so larger than the bracket face in each direction (Fig. 14), and about 1 in. or $1\frac{1}{2}$ in. thick. This takes up some of the inequalities of the wall surface.

It is obvious that if the bracket was bolted up with a high place under it as in Fig. 15, it would probably fracture when the bolts were tightened. On comparatively true surfaces

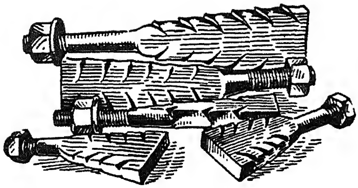


Fig. 16.—Rag bolts used for holding brackets or floor fittings and set in cement

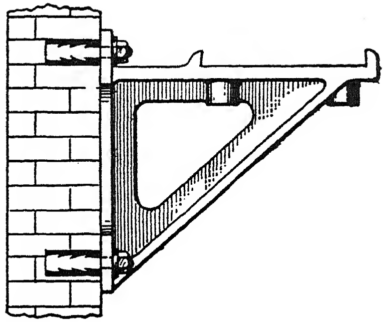


Fig. 17.—Bracket held by rag bolts set in wall in cement

such as steel joists, columns, or concrete piers or walls, this point would not arise.

Rag-bolt Fixings for Wall or Floor

It is sometimes not convenient to take the holding bolts right through the walls, or the fixtures may have to be fitted to a concrete floor, in which cases rag bolts are used (Fig. 16). Suitable slots to take the bolts are cut in the brickwork with a chisel, taking care not to disturb the bond of the bricks or to break them by too heavy blows. The bolts are then set in with cement, two of sand to one of cement, a light wood template is slipped over them to ensure that the correct position is maintained, and the cement is allowed a day or so to set before removing the template and fitting the bracket (Fig. 17).

Rag Bolts in Concrete Floor

When used in a concrete floor the rag bolts are sometimes set in with molten lead instead of cement.

Not Suitable for Heavy Work

It is not advisable to use rag bolts for any shafting above 2 in. diameter on walls as the support provided is much less than that of bolts passing through the walls with plates under the heads, and they are therefore not suitable for heavy work.

It is now common practice to drive line shafting direct or positively, the motor being placed close up to the shaft and connected by chain or spur pinions. No special arrangement of the shaft or pulleys is called for by this method of driving, apart from the necessity of placing a bearing on either side of the chain or spur wheel to avoid any springing of the shaft, which in the case of gear driving would cause very rapid wear of the wheels and noise and jarring in the driving.

Chapter VII

INSTALLING MACHINE TOOLS

A MACHINE tool is of particular importance in regard to its whole treatment, because it has to generate accurate forms. Hence faulty foundations, settings, adjustments, changes during service, imperfect slides and bearings, inadequate lubrication. and other defects must be guarded against.

Stability of Frames and Beds

There are three main principles to consider about the foundation of a machine tool: (1) firmness to prevent vibration; (2) solidity so that the levelling can be performed accurately; and (3) permanence with the minimum risk of settlement taking place, which distorts the frame, bed, and other elements.

Types of Framing and its Construction

Two kinds of framings are employed, according to the type of machine and its size. One, of fairly moderate dimensions, is so rigidly cast of box form, with plentiful ribbing and webs, that it will remain stable on any foundation. It has three-point support, and is machined while resting on the three feet, so guaranteeing truth. Even if the foundation is not level, or settles afterwards, such a frame will not warp.

The other sort, being so long that it cannot possess the self-sustaining character, must be wedged up at several points until true, and may require to have periodical testing and correction, according to the class of service and the precision demanded in the work.

Cement Grouting to Absorb Vibration

A variation on the three-point system consists in fitting a swivel-joint leg at the right-hand end of a lathe, thus providing for automatic adjustment to suit an uneven floor, and the bed never twists. Even when a three-point style of bed is in question, and it rests only on its pads, cement may be run under and around for the purpose of absorbing possible vibration set up, sometimes from outside sources. Such treatment is specially important in regard to grinding machines, particularly when there are overhanging parts liable to shake.

Types of Foundations

Foundations include wood floors, stone, brick, or concrete. In the first-named preference should generally be given to locating the machine directly over a beam.

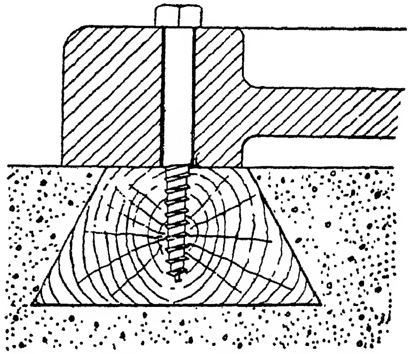


Fig. 1.—METHOD OF PROVIDING HOLD FOR COACH-SCREW IN CONCRETE FOUNDATION

Levelling and Fixing on Foundation

Levelling is effected by means of wedges, and fixing by coach-screws or bolts. When concrete forms the support, screws can be run into wood blocks embedded in the concrete, as seen in Fig. 1, but many of the heavier machines are never bolted down, the only thing done being to place stop-pins at suitable locations just to prevent the possibility of shifting. Simple wood or steel wedges are utilised to adjust beds and frames on their concrete foundations, but the tendency is towards providing more precise devices with the machines, either lugs with vertical screws or screw-operated wedges.

Levelling Screws

When screws are fitted they press on steel plates sunk a slight distance, and after correct level has been effected, the underside of the bed is run up with grouting. Fig. 2 explains the arrangement along the foot of a

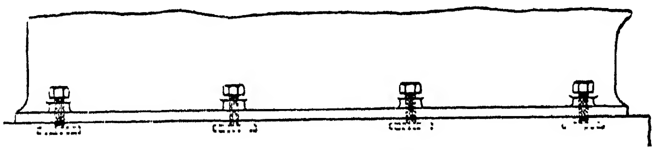


Fig. 2.—SYSTEM OF LEVELLING BORING-MACHINE END
Using screws, grouting being afterwards run under the base.

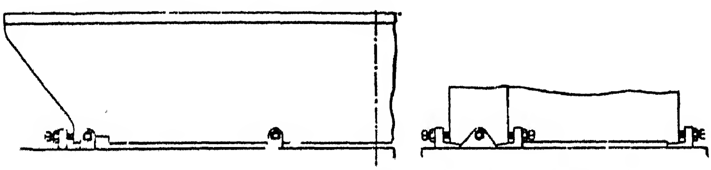


Fig. 3.—HALF-ELEVATION AND END VIEW OF GRINDING-MACHINE BASE
Showing levelling wedges and end stops.

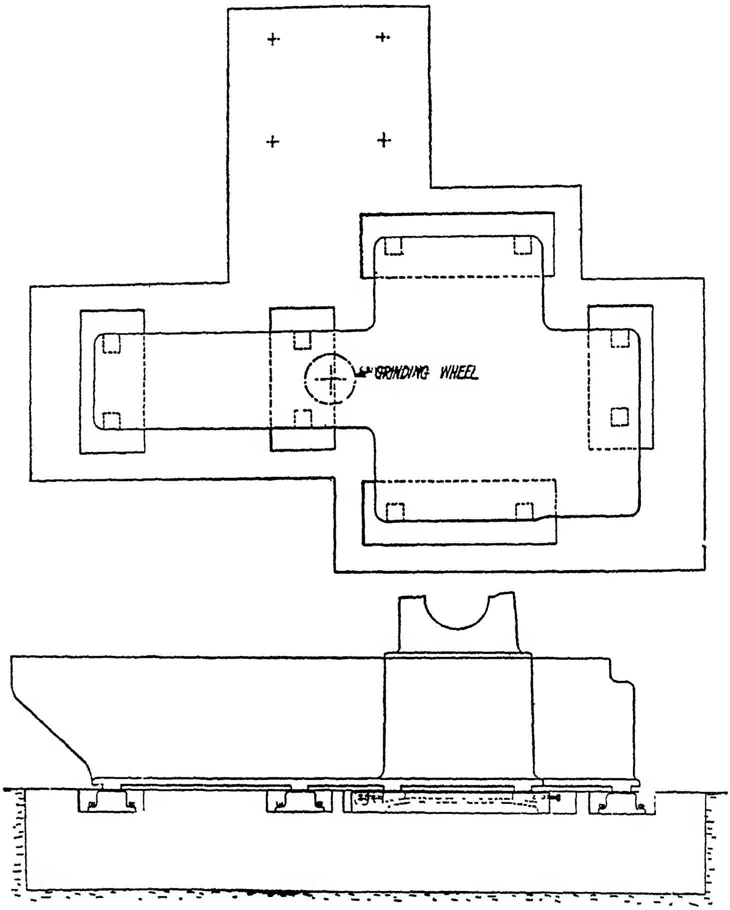


Fig. 4.—LAYOUT OF SET OF WEDGE BLOCKS TO LEVEL CHURCHILL PLANO-GRINDER
When adjustment of wedge blocks in the pits is completed, they are grouted in position.

bed for a Pearn-Richards universal boring, facing, and milling machine. Large T-slotted plates, as employed on travelling-column horizontal-spindle boring machines, have the levelling screws sunk below the top surface of the plate, with squared end for manipulation by box spanner.

Wedge Adjustments

Wedges include some connected to the base, others independent. The former feed forward or backward by operation of the screws passing into the base. Independent wedge outfits, necessary for planing,

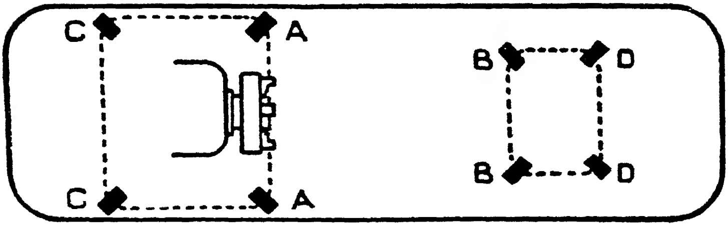


Fig. 5.—Levelling a turret lathe

The spirit level is first placed across the bed of the machine near the headstock. Iron wedges *A* are then driven under the inner corners of the feet at the headstock end of the lathe. Adjust the wedges until a correct reading is given on the spirit level. Place the spirit level across the opposite end and level up by means of wedges *B*. Take a further reading at the headstock end to see that the alignment has not been disturbed. When the bed is perfectly level, wedges *C* and *D* should be lightly tapped underneath to give support. The spaces between feet and foundation should then be grouted up.

milling, grinding, and other machine beds, consist of units each comprising a substantial sole-plate, and a wedge sliding thereon, by one screw, or a couple, fore and aft. Graphite between the meeting faces will ensure a smooth steady motion, permitting adjustment to be made without jerkiness.

Tests for Accuracy of Setting

Tests for truth of levelling vary according to the kind of datum surfaces which are present. A simple bed can receive the spirit level direct, or on a straight-edge, if gaps must be spanned. When there are V's, as in a planing or grinding machine, the top edges adjacent thereto may have been planed at the same setting, and a straight-edge can be laid over these edges to rest the level upon. Generally, however, two ground bars of uniform diameter are laid in the V's to put the straight-edge on.

Longitudinal condition is tested with straight-edge laid along the V's, and level on top of it. Or a wire is strained between supports attached to the ends of the bed, midway between the V's, and a special gauging indicator fixed on the straight-edge, which rests upon the ground bars, tried along the wire successively the whole length.

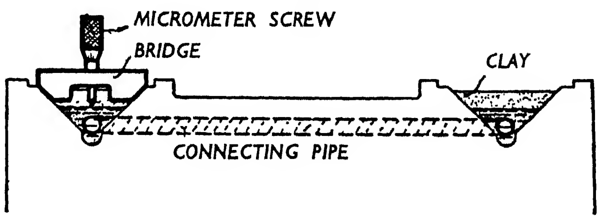


Fig. 6.—Surface of liquid and measuring point
Using vees of bed as water channels when erecting machine.

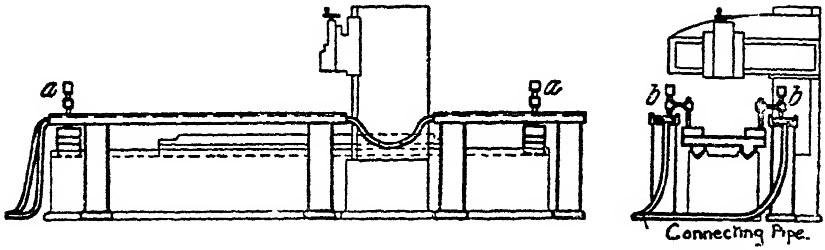


Fig. 7.—Checking the movement of a planing machine using two lengths of channel iron as liquid-container, measuring points *AA* lengthwise, *BB* crosswise

Testing for Settlement after Installation

These tests must be made occasionally, after installation, as the shocks and severe duty of a planing machine are liable to induce settlements. It should be mentioned that if the machine has been set up properly, the table will obviously be true, as it was planed in the maker's shop ; it is a mistaken policy to plane it over after erection, because if such a practice is found necessary the trouble lies in the foundation.

Countershafts

Countershaft arrangements involve more care in setting up, to be sure of parallelism so that belts will track properly.

This kind of location is a matter of direct measurement from the countershaft to the machine bed ; or strings can be suspended from near the ends of the shaft, and measurement taken along horizontally to the machine. Levelling of a countershaft may be very nearly correct if beams or stringers are fairly true, only slight adjustment by shims under hangers being necessary.

It is best to deaden sound by interposing some kind of insulator between the feet and the girder, as wood, leather, canvas belting, rubber. Convenience of mounting may be achieved by employing clips, which can be slid along to any spot and facilitate alterations at any time. Cross girders for supporting hangers are likewise attached to main beams in a similar manner. Special care should usually be observed to use the specified sizes of driving pulleys from the lineshaft. This not only refers to the speed of grinding wheels, where efficiency and safety are in question, but to the correctness of speed and feed tables cast on or fastened to the machine, these being rendered false and misleading.

Selection of Belts

Proper selection of belts is also very important, both as to straightness, flexibility, and good jointing. Some types of machines are much

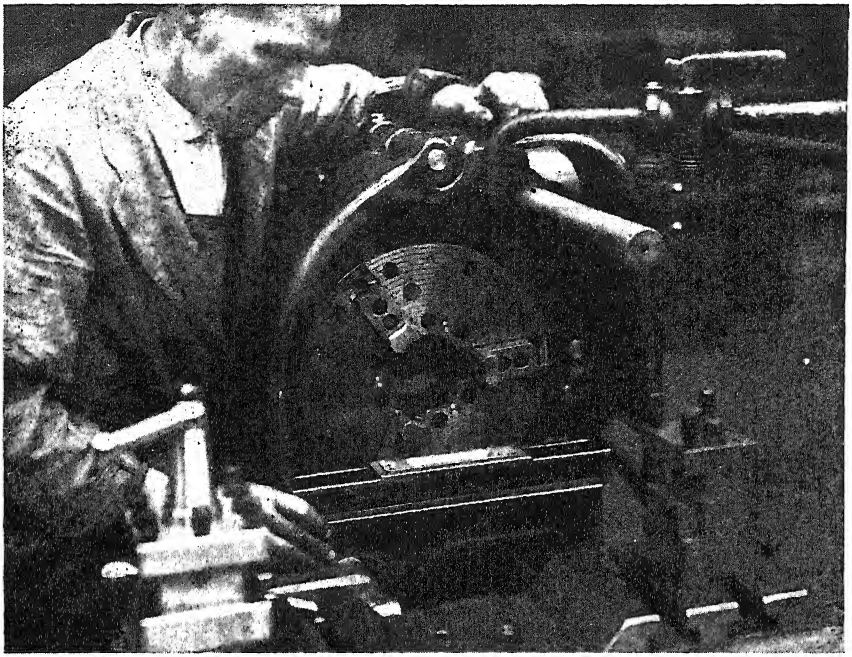


Fig. 8.—Testing machine bed for alignment

affected by bad belts failing to deliver good results, this being most noticeable on grinders, where vibration causes chatter marks.

ERECTION OF POWER HAMMERS

While the erection of a hammer is a reasonably simple and straightforward matter, for which adequate provision is made by the drawings and instructions issued by the makers, the preparation of the foundation prior to erection is a most important point to which too much care can hardly be given.

LAYING THE FOUNDATION

On Good Firm Ground

A good foundation is essential if the hammer is to work efficiently. The weight and proportions of the foundation for any particular hammer naturally vary according to the nature of the ground. The makers' drawings should be regarded as the minimum suitable for good firm ground, and wherever this description does not apply, or it is specially

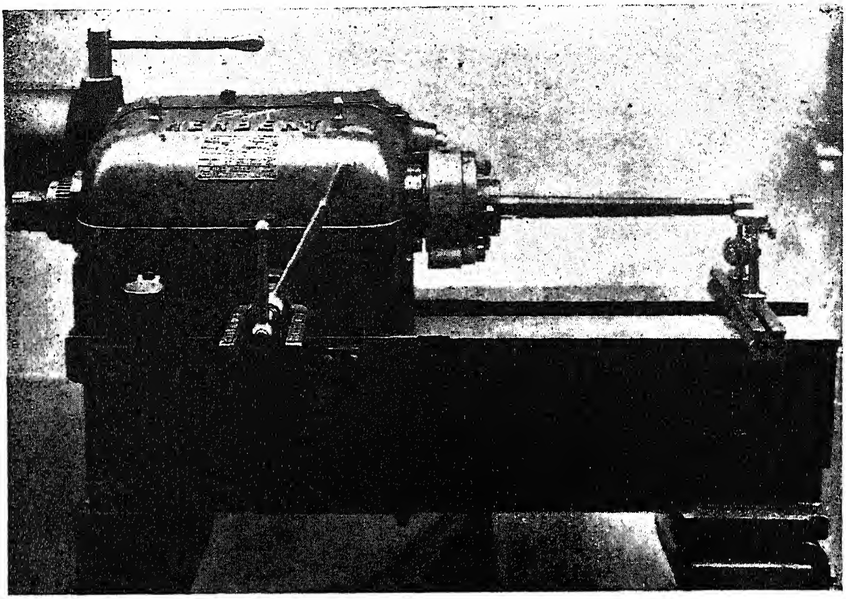


Fig. 9.—METHOD OF TESTING CAPSTAN HEADSTOCK FOR ALIGNMENT

Using a spindle-nose adapter and testing bar. This illustrates arrangement of gauges for the test.

important to minimise vibration, the concrete which forms the basis of the foundation should be enlarged.

On Soft Ground

On soft or " made " ground it is necessary not only to increase the horizontal dimensions of the concrete, but also to excavate until, if possible, a firm bottom is reached. Failing such bottom, resort may have to be made to piling.

On Rock

On the other hand, where the foundation rests on rock the dimensions of the concrete should not be decreased, but provision should be made for an extra depth of timber under the anvil block so as to cushion the blow. If this precaution is not taken the anvil block may be so solid as to cause constant piston-rod breakage.

The Concrete

The concrete itself should be thoroughly strong and should be allowed ample time to set before the hammer is put to work. A suitable mixture is as follows :

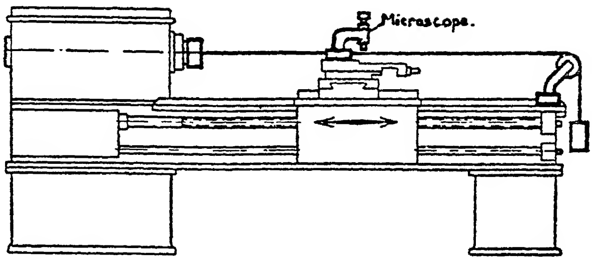


Fig. 10.—LATHE ALIGNED BY TAUT WIRE

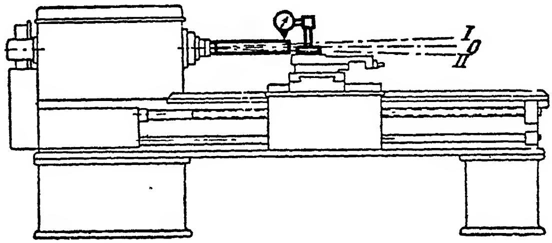


Fig. 11.—MANDREL RUNNING OUT OF TRUTH MUST BE SET TO MEAN POSITION (*O*) BEFORE TESTING FOR PARALLELISM WITH BED

One part, by volume, good-quality Portland cement, one part clean sharp sand, four parts broken stone or bricks (but not furnace bricks) of size to pass through a 2-in. ring. A facing at least 1 in. thick on the upper surface of the concrete and the portions immediately above and around the foundation plates should consist of two parts clean sharp sand and one part cement.

Hammers of the arch form and girder form usually have three quite separate blocks of concrete, one under the anvil block and one under each standard. While this arrangement is preferable under ordinary circumstances, it is not essential, and if more convenient a solid block of concrete may be used.

Placing Timber for Cushioning

For the timber used between the concrete and the hammer any good wood may be used, but pitch pine and oak are particularly suitable. The timbers should be carefully fitted to the concrete and to the anvil block and base-plate of the hammer.

Where an extra depth of timber is required baulks set on end and bolted or strapped together can be employed with advantage.

Methods of Minimising Vibration

To minimise the vibration caused by a hammer, the concrete block should be as large as possible. Assistance can also be obtained in the same direction by the use of cork, felt, and other proprietary anti-vibration substances under the anvil block, or by increasing the depth of the timber. A further scheme sometimes adopted is to dig a moat all round the hammer

foundation extending 2 ft. or 3 ft. below the bottom of the concrete, a brick wall being built round the outside of the moat and loose plates put across from the outside to the hammer to provide a floor. This is a thoroughly good scheme for preventing vibration travelling sideways, but is naturally somewhat expensive.

Arranging Foundation Bolts in Concrete

The bolts by which the hammer is secured to the foundation should not be permanently fastened into the concrete, owing to the difficulty that would be caused in the event of breakage.

The soundest arrangement is to build a cast-iron anchor plate into the concrete and above it a vertical wooden box. A tee-headed foundation bolt can then be dropped through a rectangular hole in the anchor plate, and turned through 90° to fit into a recess on the inside of the plate to prevent further rotation.

A little extra care and outlay on the foundation may increase the efficiency of every blow the hammer strikes in a life of twenty, thirty, or more years.

Placing Sole-plate in Position

When the anvil block is set and levelled, the sole-plate is next placed in position, set centrally to the anvil block and levelled by the machined facings for the standards.

The level of the foundation should be such that about 1 in. of space is left for grouting between the surface of the concrete and the underside of the sole-plate. Temporarily support the sole-plate on parallel steel packings and tighten the foundation bolts to maintain it in its correct position.

When to Grout Up Sole-plate

It is usual to erect the hammer completely before grouting up the sole-plate, as this enables a final check to be taken and any necessary adjustments made.

Completing Erection

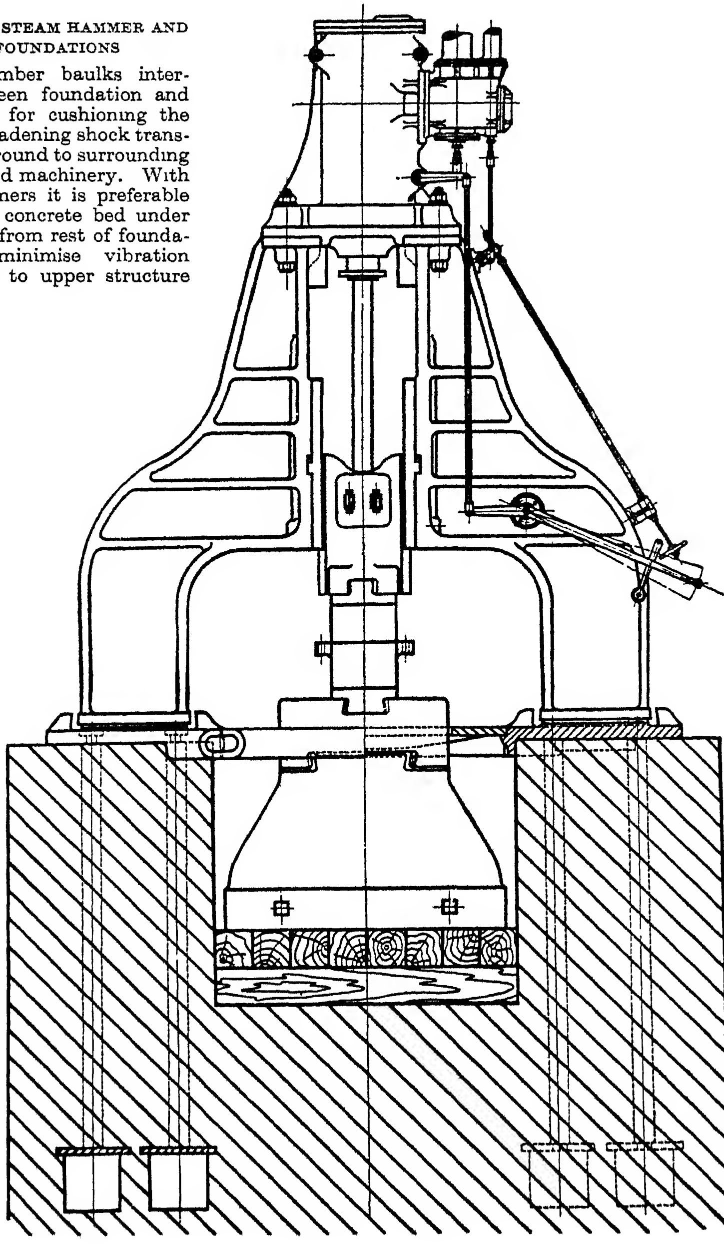
After the sole-plate is fixed, the remainder of the erection is comparatively straightforward, as it is only necessary to work to the reference marks stamped on the individual parts during erection at the maker's works.

Arrangement of Steam Pipes

In fixing steam piping care should be taken that it falls in the direction in which steam travels. A steam trap should be arranged at the end of

Fig. 12.—A STEAM HAMMER AND ITS FOUNDATIONS

Note timber baulks interposed between foundation and anvil block for cushioning the blow and deadening shock transmitted by ground to surrounding buildings and machinery. With larger hammers it is preferable to separate concrete bed under anvil block from rest of foundations to minimise vibration transmitted to upper structure of hammer.



the steam main, or steam separator and trap between the boiler and the first hammer.

All branch steam pipes to the hammers should be taken from the top of the steam main and the last branch should be 3 ft. or more from the end of it. Large bends, not sharp elbows, should be employed wherever possible. It is a convenience to have flanged joints near to the hammer and pipes near to the hammer should not be rigidly fixed in view of the unavoidable vibration.

Fixing Drain Pipes

In fixing the drain pipes it is advisable to arrange a valve on each of the pipes from the stop valve, piston valve, and cylinder respectively before they are joined together. The valve on the pipe from the piston-valve chest (which is exhaust steam) is not essential, but is advisable. In any case, care should be taken that the drain pipes do not allow live steam to escape into the exhaust system.

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